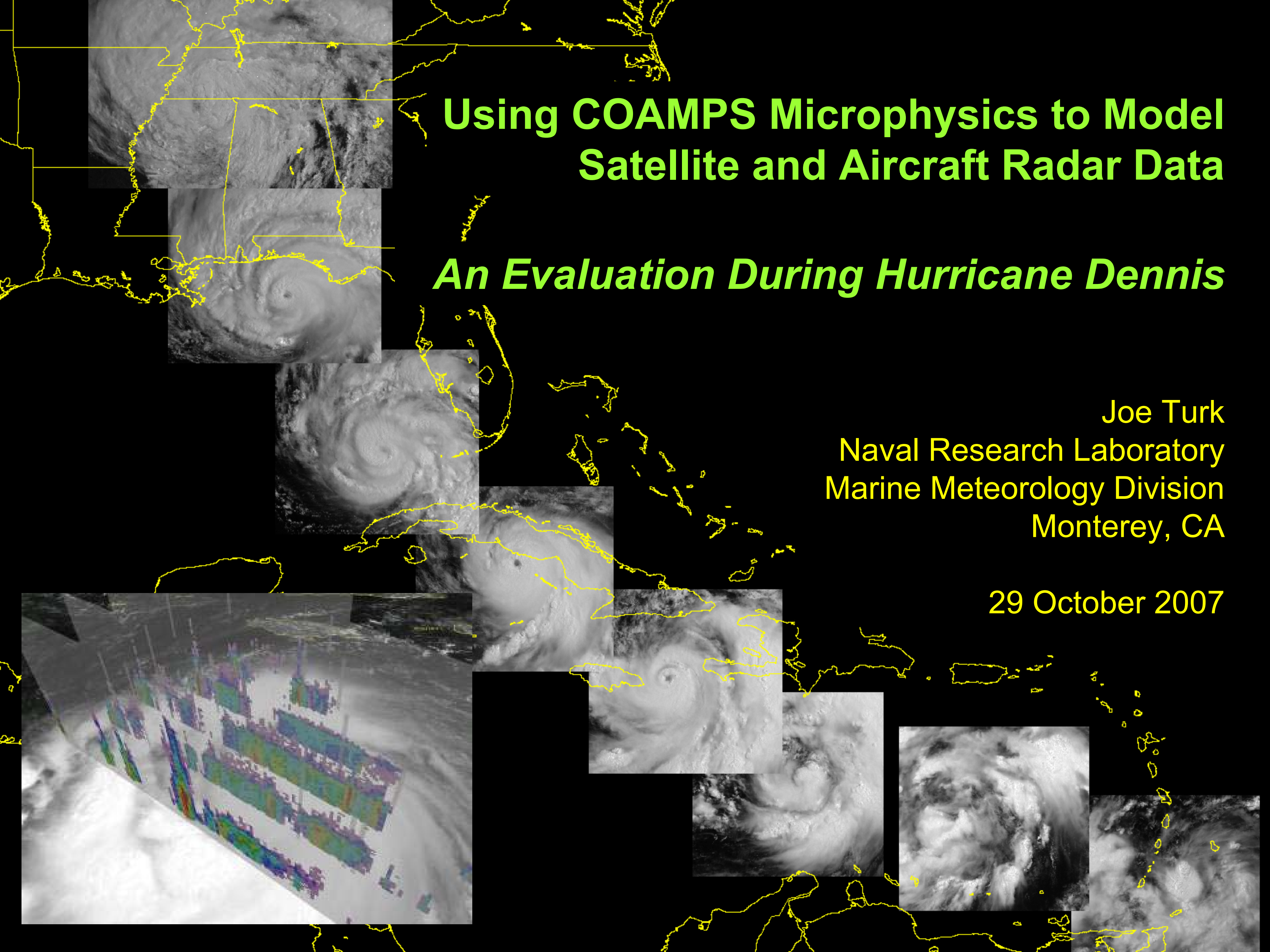

Using COAMPS Microphysics to Model Satellite and Aircraft Radar Data

An Evaluation During Hurricane Dennis

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29 October 2007

Acknowledgments

• Sue Chen (NRL) for providing the COAMPS simulations and technical advice

• NASA Tropical Cloud Systems and Processes (TCSP) experiment participants and NASA support

• Steve Swadley, Cristian Mitrescu, Ben Ruston, Clark Amerault and Gene Poe for discussions on radiative transfer modeling

• Steve Guimond (FSU) for EDOP data analysis and interpretation

Motivations for this Study (1)

- Satellite imagery and derived products provide 4-D depictions of environmental scenes (e.g, clouds) just like mesoscale models do

- Realization of the A-Train in the afternoon (1:30 PM) ascending orbit providing complementary passive/active observations on aerosol, cloud and rain microphysics

- Focused field experiments (CAMEX, TCSP, NAMMA, TC4) and development of new aircraft sensors (lidars, radars, spectroradiometers)

- Focused model microphysical simulations (e.g Li and Pu, 2007; Hashino and Tripoli, 2007) and intercomparisons with satellite radiances and radar (McFarquhar et.al, 2006), directed at hurricane intensification

- Complex interactions between PBL, cloud microphysics and storm dynamics contribute to hurricane intensity change

Motivations for this Study (2)

• Starting in the 1990s, microwave-based precipitation retrieval techniques began to use cloud resolving models to generate “cloud radiation databases”, which form the a-priori information in the retrieval process (e.g, TRMM)

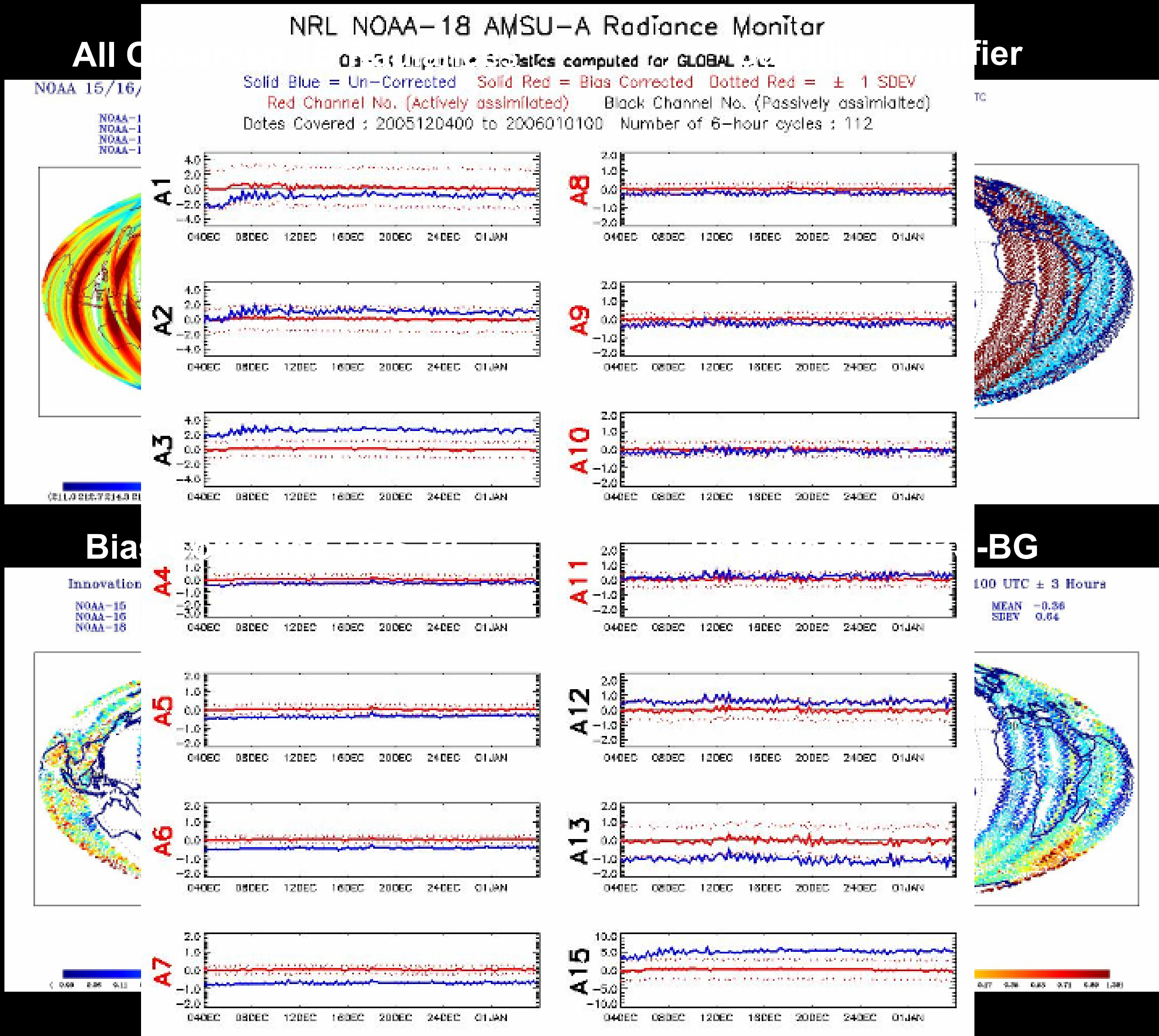
• However even an expanded set of model runs cannot replicate the entire ensemble of possible “observable” atmospheric states; moreover, these states take on the model characteristics

• In the meantime, many organizations began to show impact related to clear-sky microwave radiance assimilation, and began to work on incorporation of cloudy/rainy radiances (upcoming JAS issue)

• Effective assimilation requires careful monitoring of “observation-background” such as routinely done for AMSU clear-sky

• How can we analyze the capability of a mesoscale model to replicate clouds and rain in the microwave regime? (e.g, COAMPS©)

Example: AMSU Radiance Monitoring



All NOAA observations ±3 hours about the analysis time

Time series (radgram) of each 6-hour analysis for monitoring trends, spikes, etc

Steve Swadley, NRL

Uses of satellite data with numerical models

Depiction

Updated imagery, animations of imagery (visible, microwave, eg NRL/FNMOC TC-Web), often compared alongside forecast fields

Retrieval

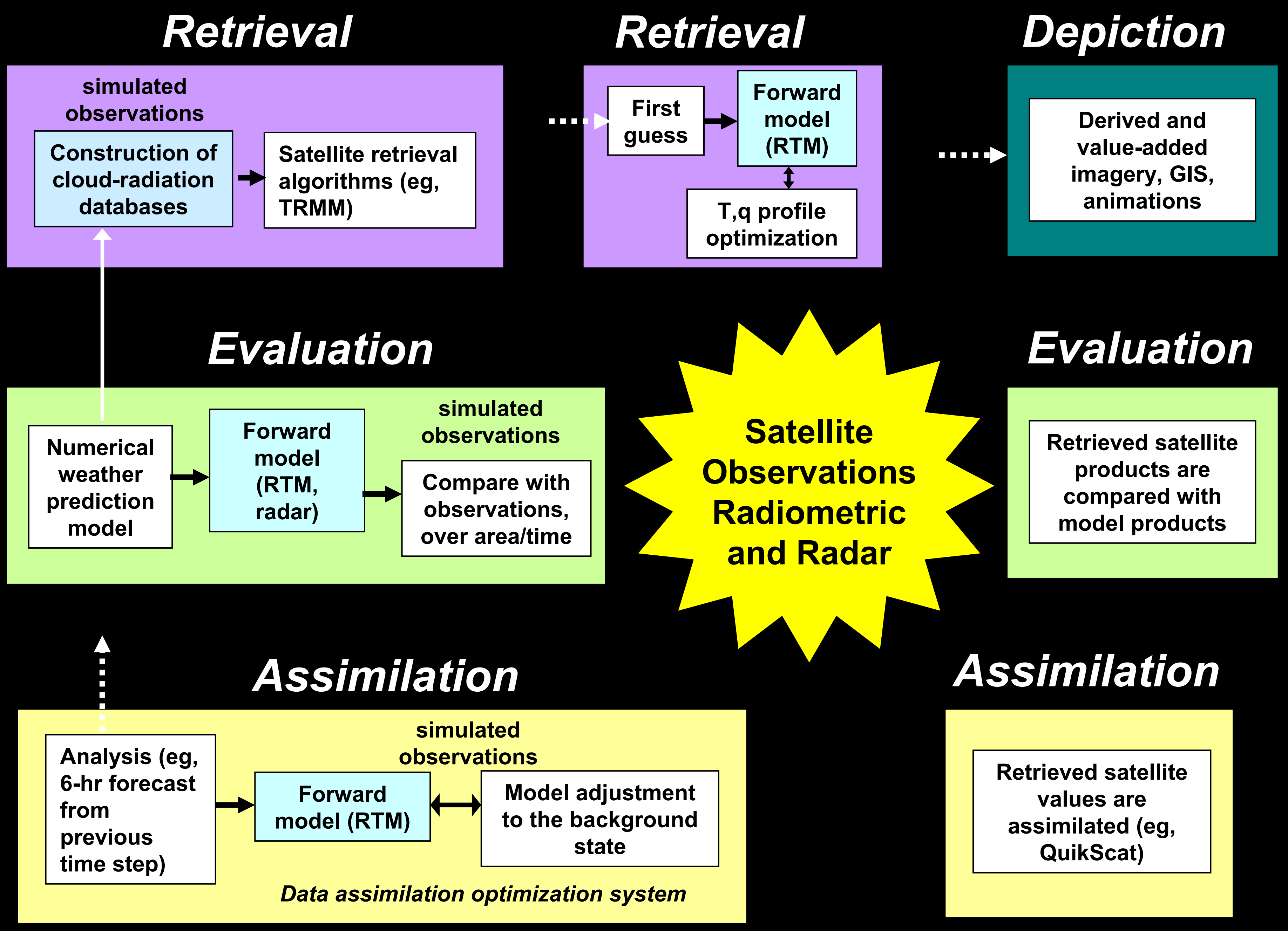
Satellite data inversion process is under-constrained and model data is often used for initialization

Assimilation

Retrieved values or satellite “observable” (radiance, radar backscatter) are used to adjust the model background state

Evaluation

How closely do the models quantitatively replicate the satellite and/or radar observations?



Retrieval
simulated observations
Construction of cloud-radiation databases
Satellite retrieval algorithms (eg, TRMM)
Retrieval
First guess
Forward model (RTM)
T,q profile optimization
Depiction
Derived and value-added imagery, GIS, animations
Evaluation
Numerical weather prediction model
Forward model (RTM, radar)
simulated observations
Compare with observations, over area/time
Satellite Observations Radiometric and Radar
Evaluation
Retrieved satellite products are compared with model products
Assimilation
simulated observations
Analysis (eg, 6-hr forecast from previous time step)
Forward model (RTM)
Model adjustment to the background state
Data assimilation optimization system
Assimilation
Retrieved satellite values are assimilated (eg, QuikScat)

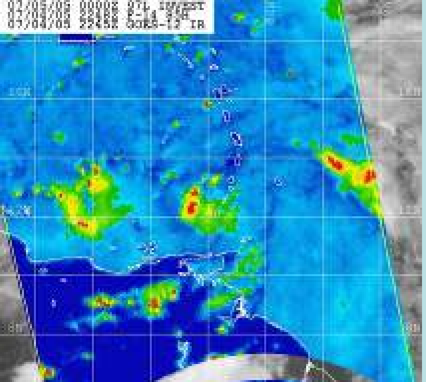
Tropical Clouds Systems and Processes (TCSP) NASA-NOAA Field Experiment

NAMMA (Cape Verde, 2006)
Focused on evolution and structure of African easterly waves and MCCs over western Africa (DC-8)

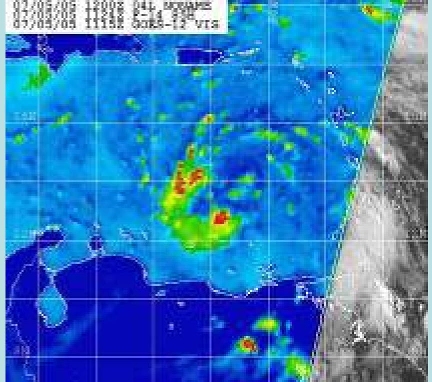
TCSP (Costa Rica, 2005)
Intent was to focus on cyclogenesis in the eastern Pacific, but shifted to the Caribbean and Gulf of Mexico due to unusual early season storms Dennis, Emily, Gert, Eugene (ER-2, P-3)

CAMEX-4 and CAMEX-3 (Florida, 2001 and 1998)
Focused on hurricane development, tracking, intensification and landfall impacts post-TRMM (ER-2, DC-8)

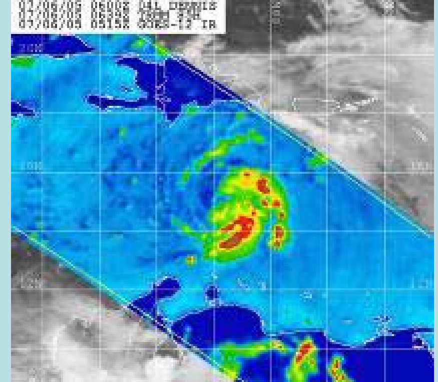
CAMEX-2 and CAMEX-1 (Wallops Island, 1993 and 1991)
Studies of 3-D moisture fields using satellite, aircraft, and ground-based instrunmentation pre-TRMM (ER-2, DC-8)



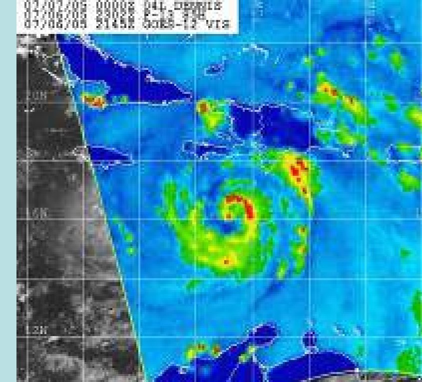
July 4 22Z- Begins as TD-4 and makes landfall in Grenada



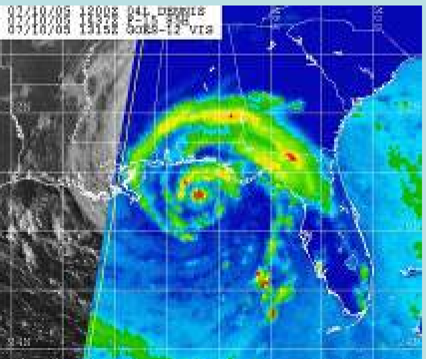
July 5 11Z- Quickly strengthens to TS Dennis



July 6 06Z- Reaches Cat-1 near S coast of Hispaniola



July 6 23Z- Rapid intensification & moves north



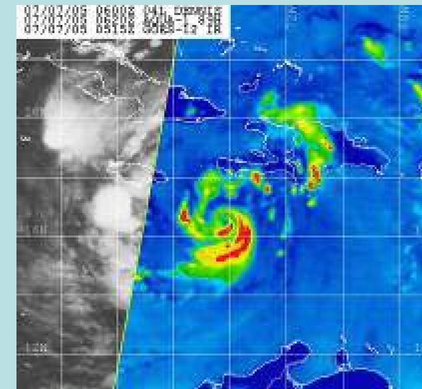
July 10 14Z- Slightly weakens near landfall

First Major Hurricane of 2005

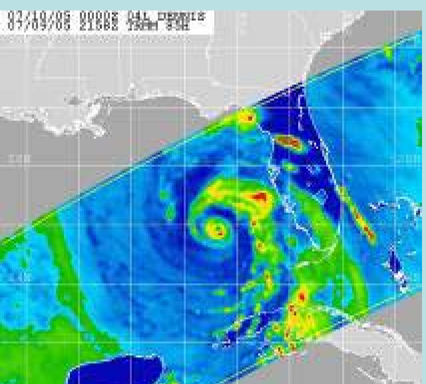
Strongest Atlantic hurricane to form before August

ER-2: July 5, 6 & 9

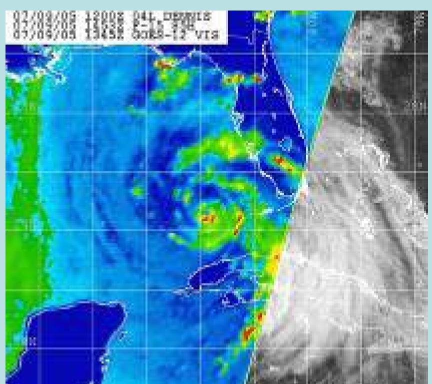
DENNIS



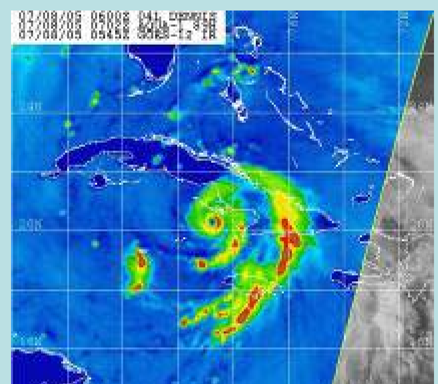
July 7 06Z- Approaches Cuba as Cat-4, 31 mb fall in 24 hrs



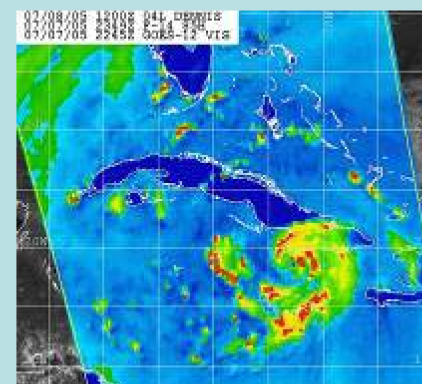
July 9 22Z- Intensification and closed eye re-emerges



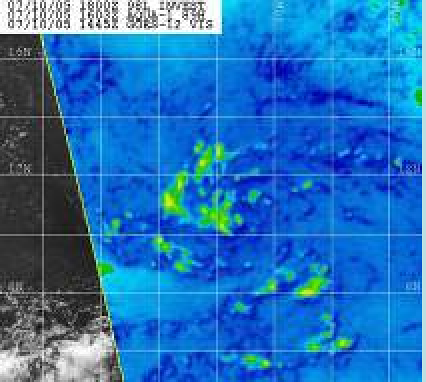
July 9 15Z- Re-intensification, 37 mb fall in 24 hrs, to N-NW

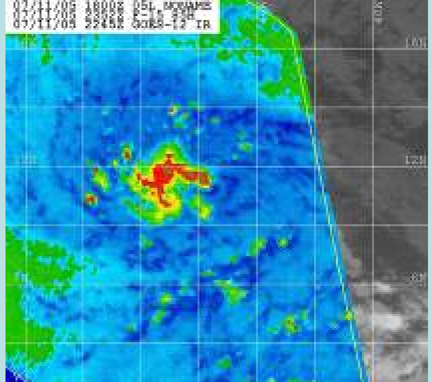


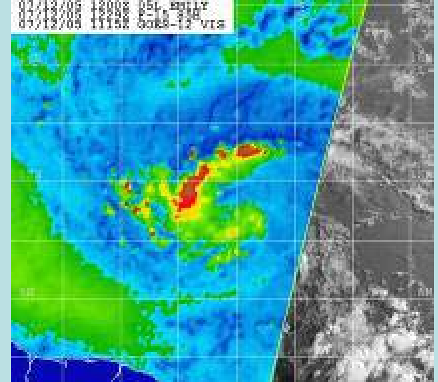
July 8 07Z- Landfall in SE Cuba, weakens while crossing

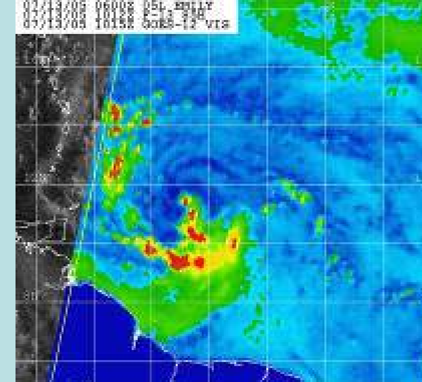


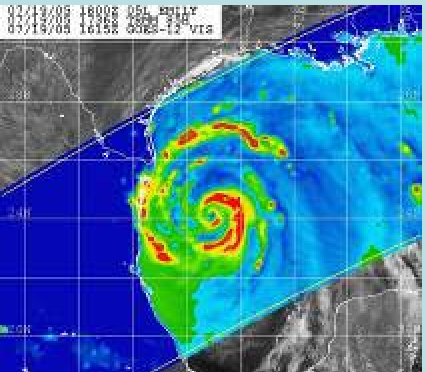
July 8 00Z- Almost at landfall in SE Cuba with 120-kts


July 10 16Z- Reaches tropical depression stage


July 12 00Z- Reaches tropical storm stage


July 12 12Z- Westerly shear & convection disorganized


July 13 10Z- Surface winds begin to pick up

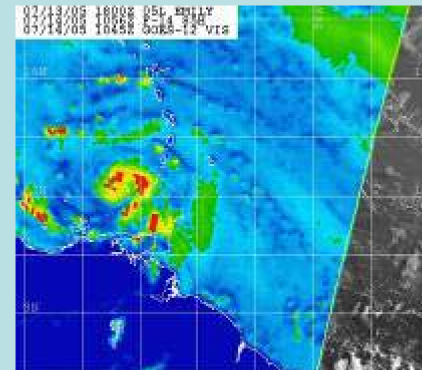

July 19 17Z- 29 mb drop over 24-hrs, landfall as cat-3

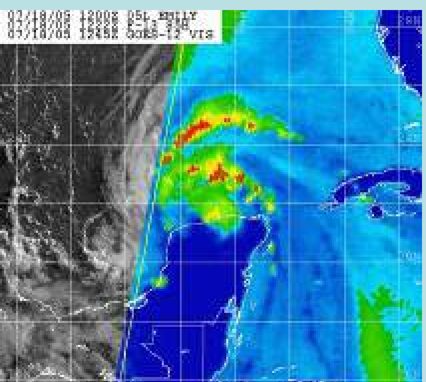
EMILY

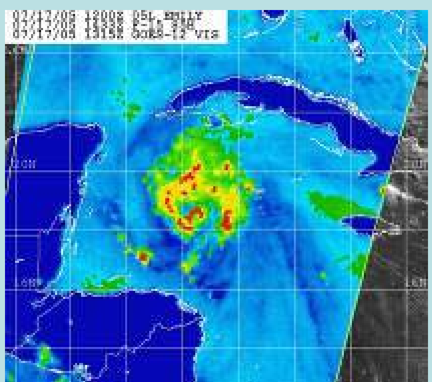
First Cat-5 of 2005

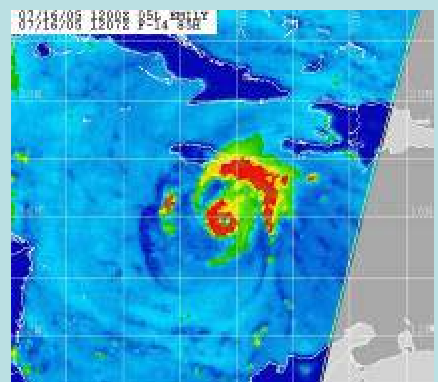
Broke Dennis' record from 6 days earlier

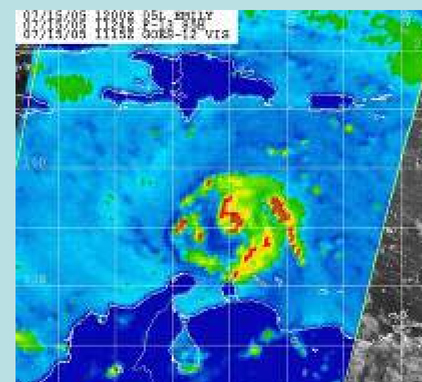
ER-2: July 17 (5 hrs)

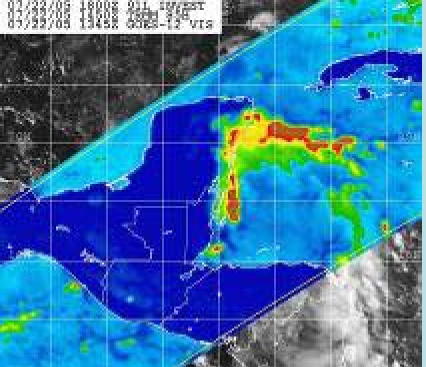

July 14 11Z- 75-kt hurricane strength, pass over Grenada


July 18 12Z- Third & final re-intensification phase begins

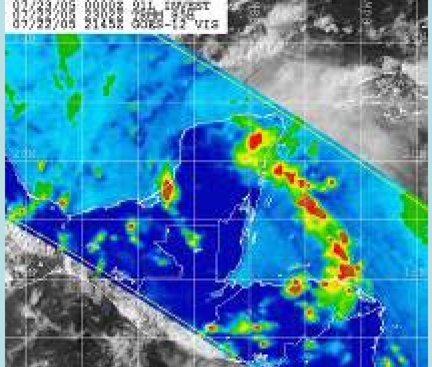

July 17 14Z- Approaches Yucatan Peninsula as cat-4


July 16 12Z- Strengthens to cat-5 SW of Jamaica

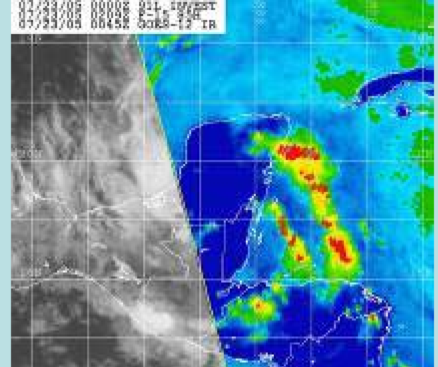

July 15 11Z- Reaches Cat-4, then weakens to cat-2



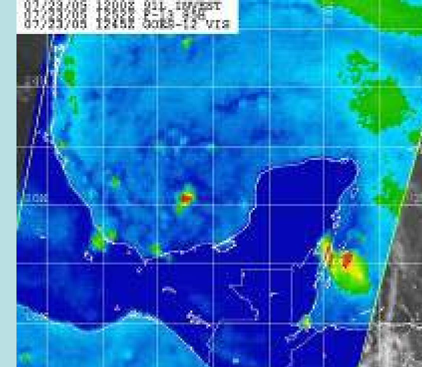
July 22 14Z- Tropical wave organizes into TD # 7



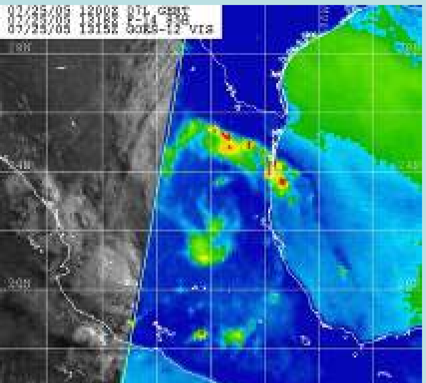
July 22 23Z- Low pressure area forms in G of Honduras



July 23 02Z- Rainfall in the Yucatan (Wilma in October….)



July 23 13Z- Crosses over Yucatan and weakens



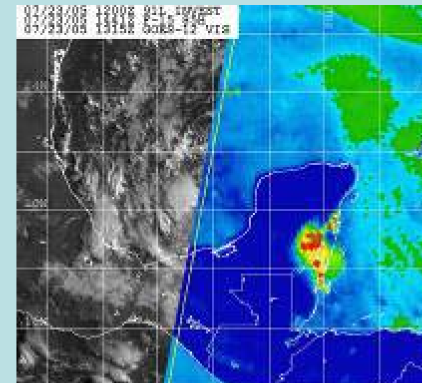
July 25 13Z- Inland rains over the Sierra Madre

Origins from tropical wave off Africa on July 10

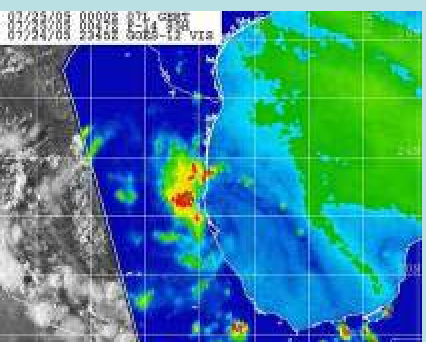
Landfall near where Emily had 4 days earlier

ER-2: July 23-24-25

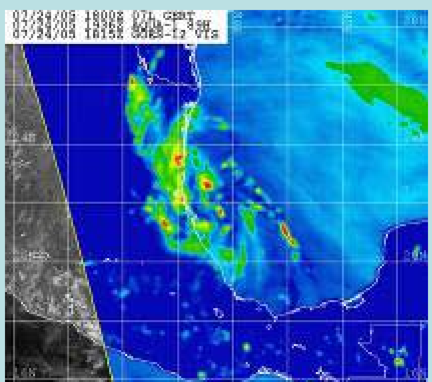
GERT



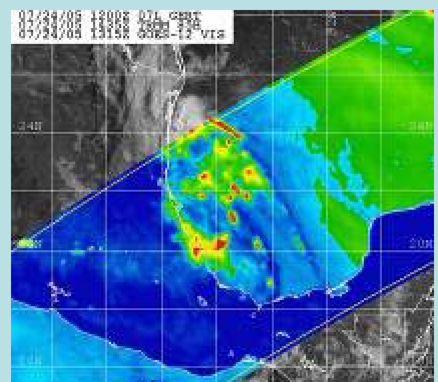
July 23 14Z- Crosses over Yucatan and weakens



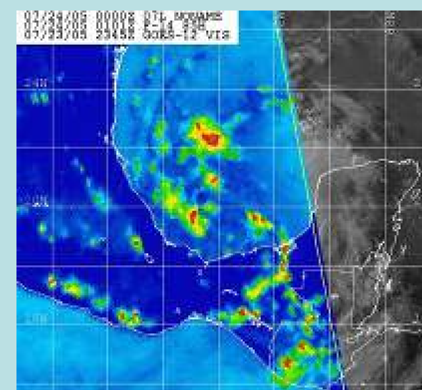
July 25 00Z- Landfall S of Tampico with 40-kts



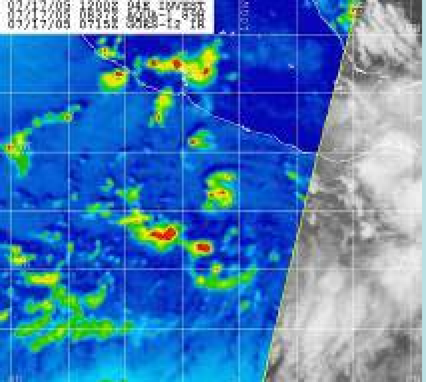
July 24 19Z- Almost at landfall



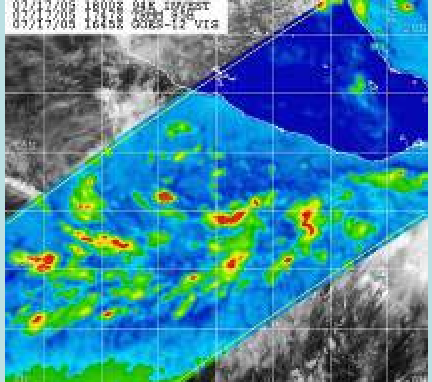
July 24 15Z- Center moves NW towards Mexico



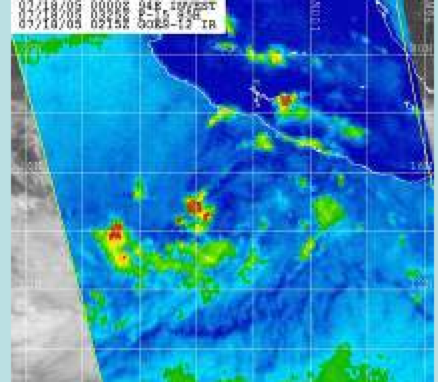
July 24 01Z- Becomes TS Gert in Gulf of Mexico



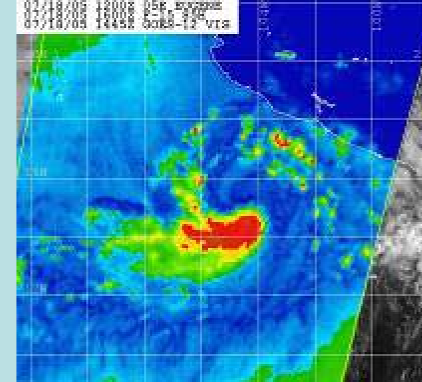
July 17 08Z- Tropical disturbance in E Pacific



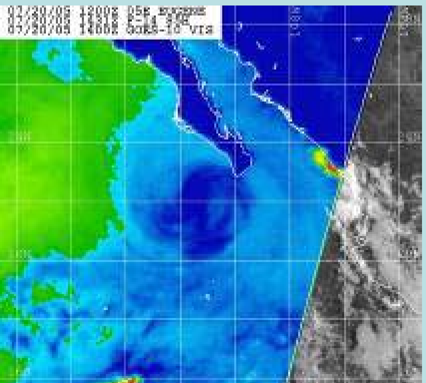
July 17 17Z- More organized convection, moves to NW



July 18 03Z- Becomes tropical storm



July 18 16Z- Circulation center defined, moves to N



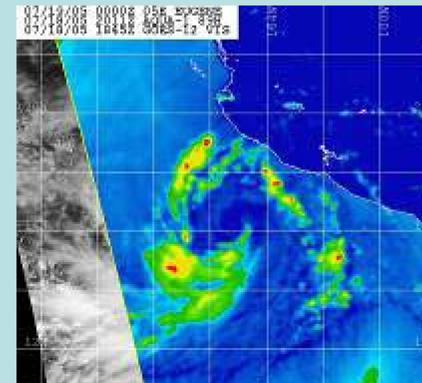
July 20 14Z- Moves offshore of Baja CA and dissipates

Briefly Threatened Baja CA

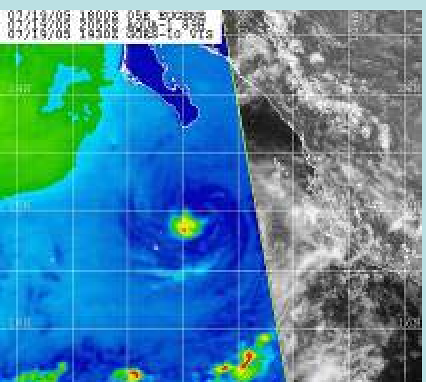
Pre-Genesis Flights

ER-2: July 15-16 (Pre-Genesis) & July 20 (50-kts)

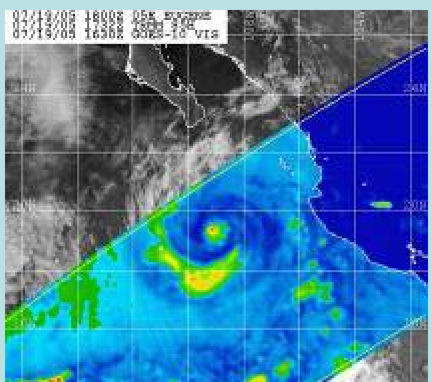
EUGENE



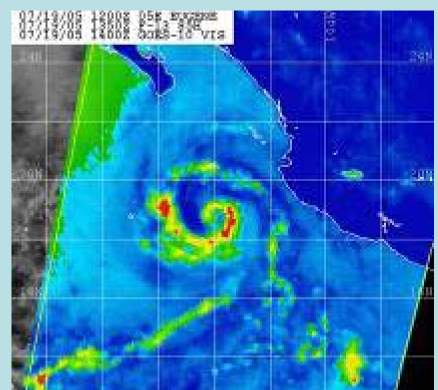
July 18 20Z- Continued N movement



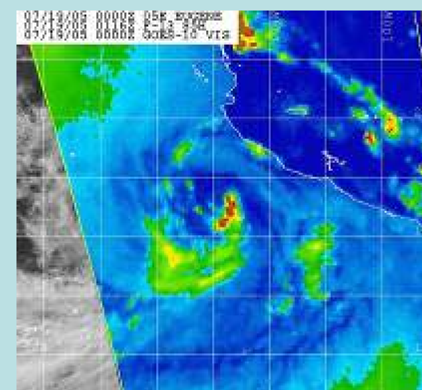
July 19 21Z- Approaches S tip of Baja CA



July 19 17Z- Warnings issued for Baja CA



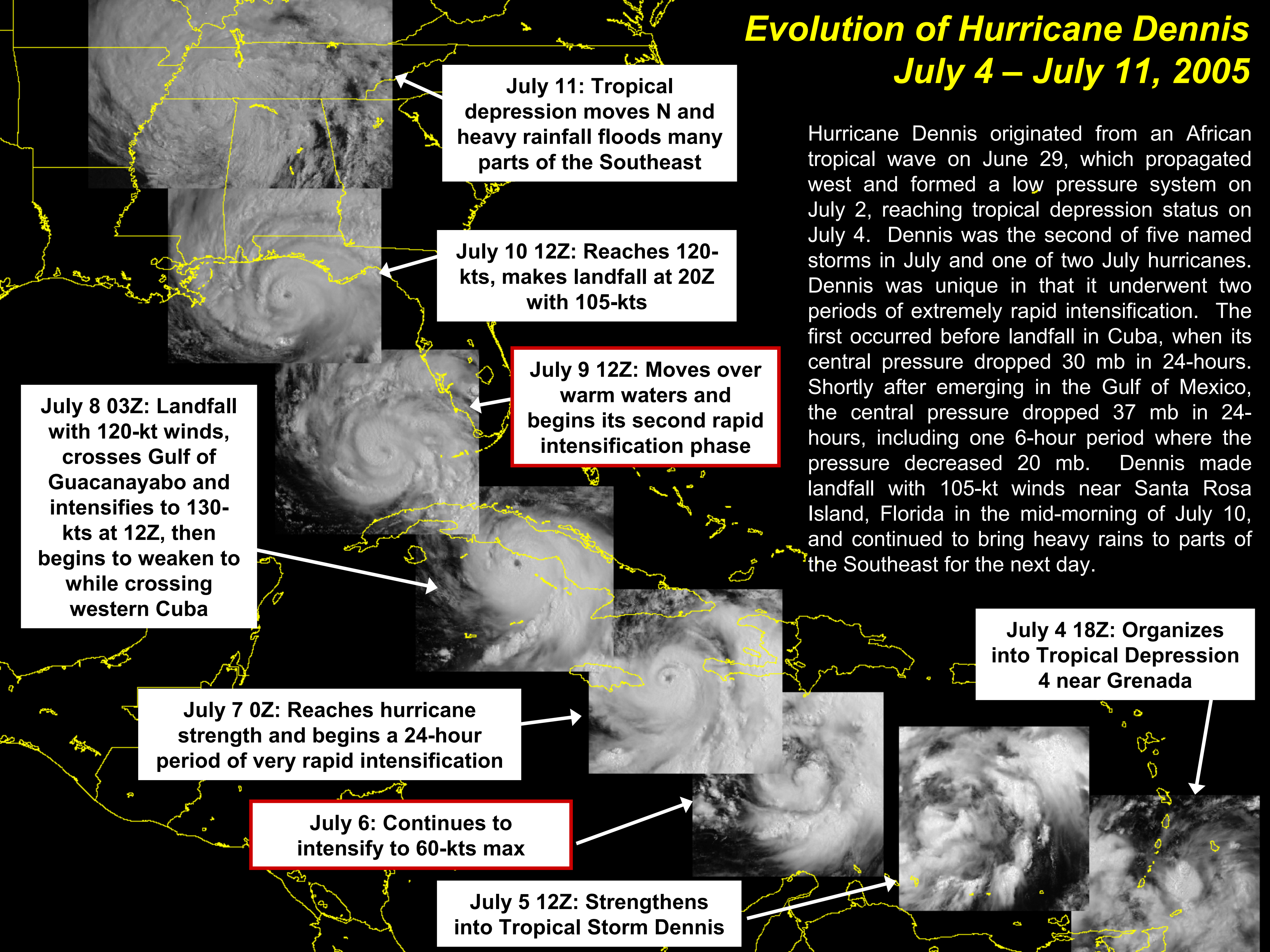
July 19 14Z- Eye becomes more defined in sat imagery



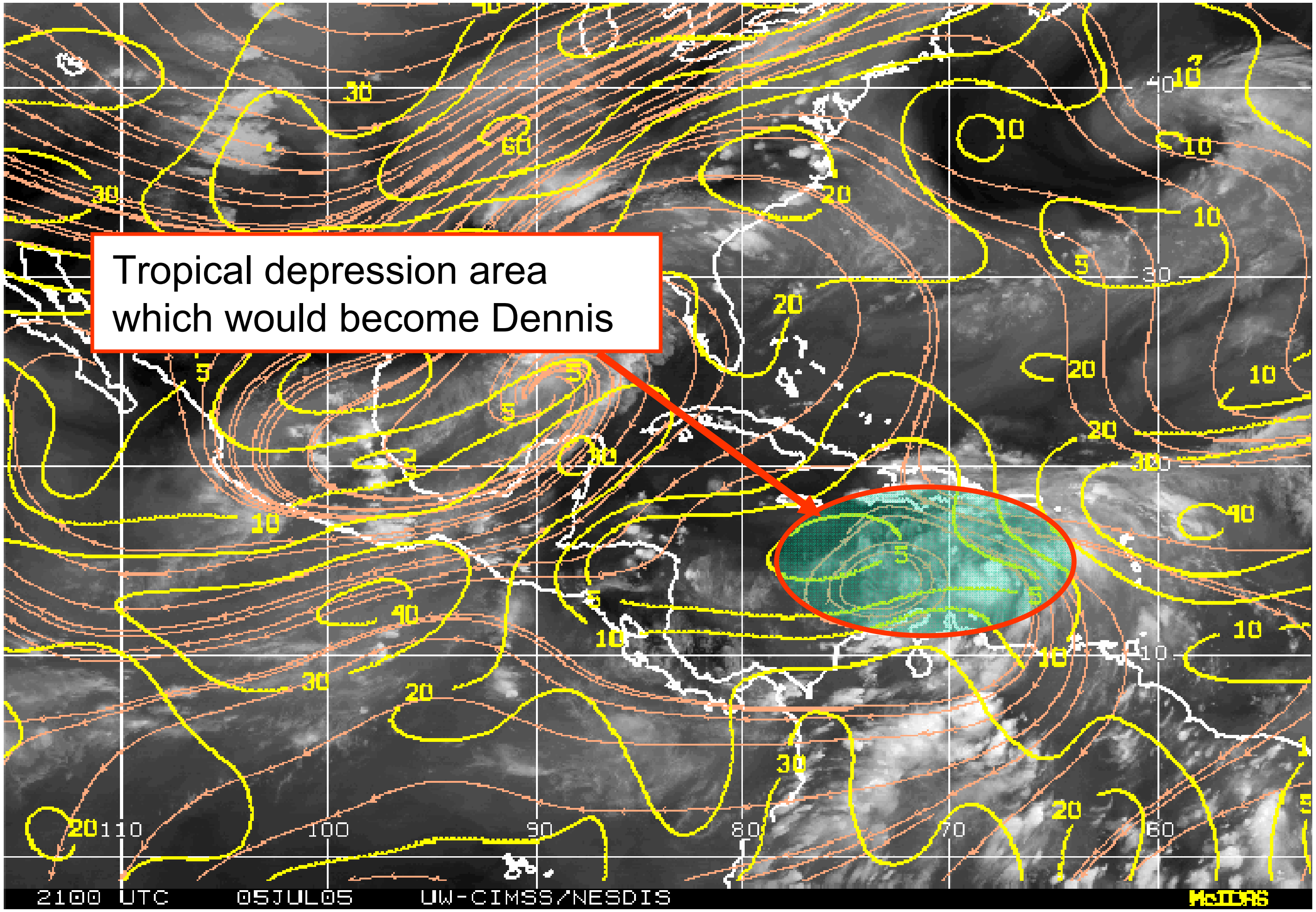
July 19 01Z- Continued N movement

Evolution of Hurricane Dennis
July 4 – July 11, 2005

Hurricane Dennis originated from an African tropical wave on June 29, which propagated west and formed a low pressure system on July 2, reaching tropical depression status on July 4. Dennis was the second of five named storms in July and one of two July hurricanes. Dennis was unique in that it underwent two periods of extremely rapid intensification. The first occurred before landfall in Cuba, when its central pressure dropped 30 mb in 24-hours. Shortly after emerging in the Gulf of Mexico, the central pressure dropped 37 mb in 24-hours, including one 6-hour period where the pressure decreased 20 mb. Dennis made landfall with 105-kt winds near Santa Rosa Island, Florida in the mid-morning of July 10, and continued to bring heavy rains to parts of the Southeast for the next day.

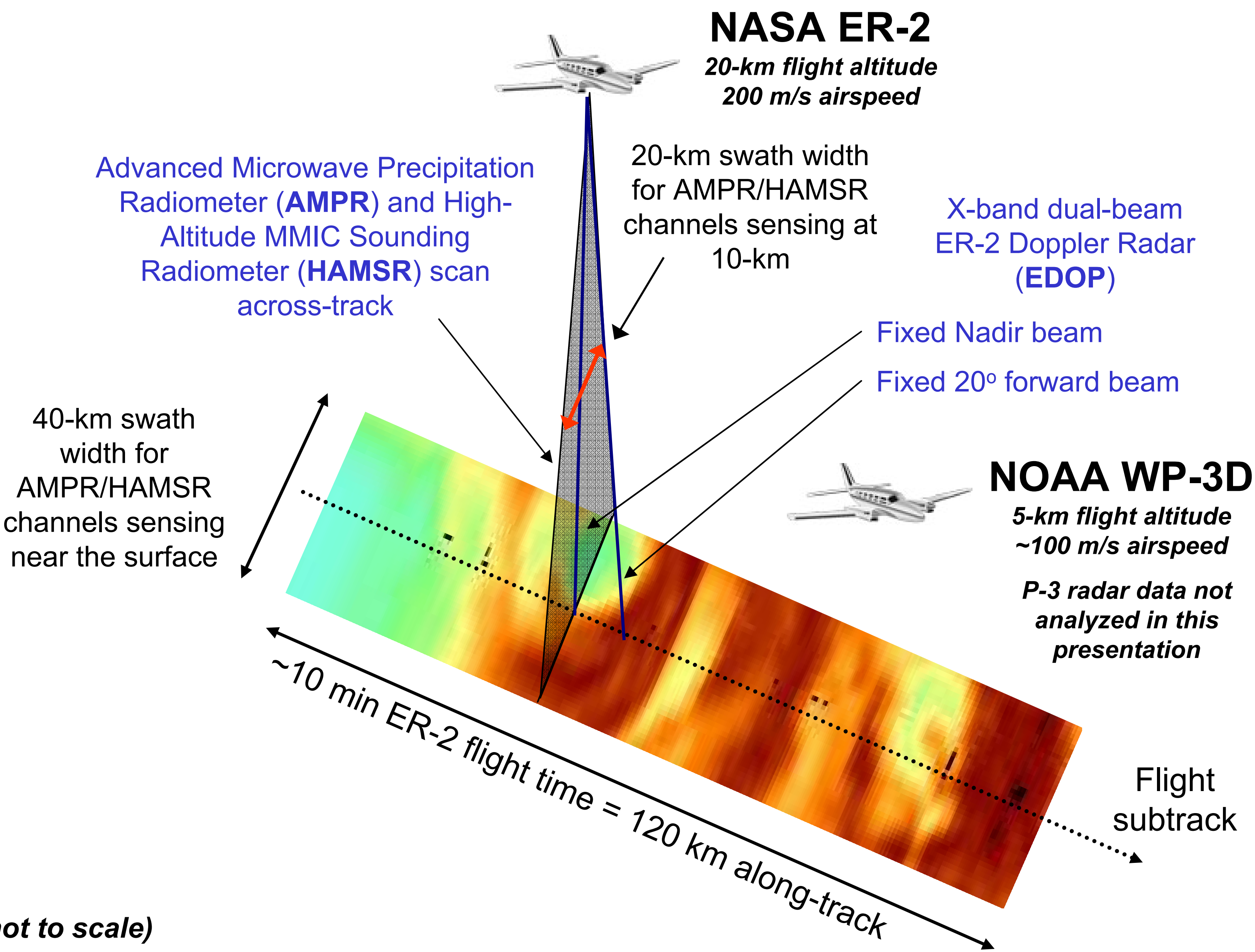


Evolution of Hurricane Dennis



UW-CIMSS wind shear (knots, yellow contours) derived from GOES-12 satellite data at 21 UTC on July 5. The contours represent the 150-300 mb winds layer minus the 700-925 mb layer. Values near 5 kts indicate minimal upper level shear, favorable for TC intensification. Figure courtesy of Chris Velden and Dave Stettner, Univ. of Wisconsin.

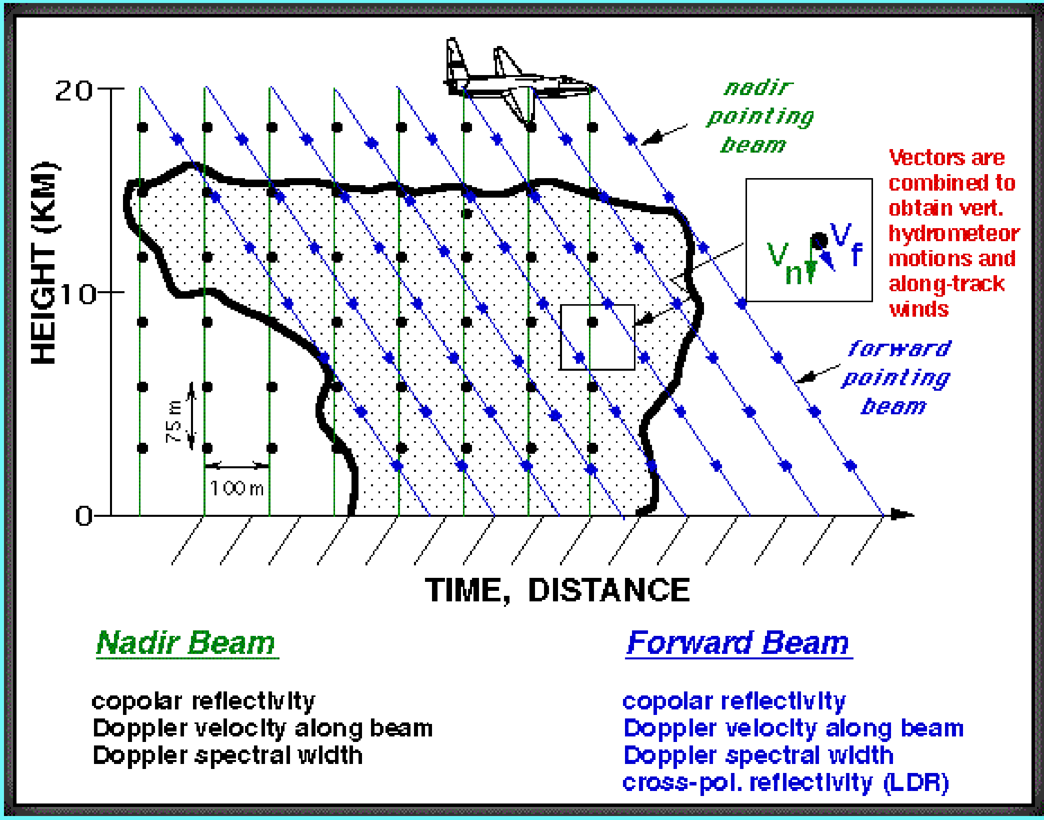
TCSP Aircraft and Instruments



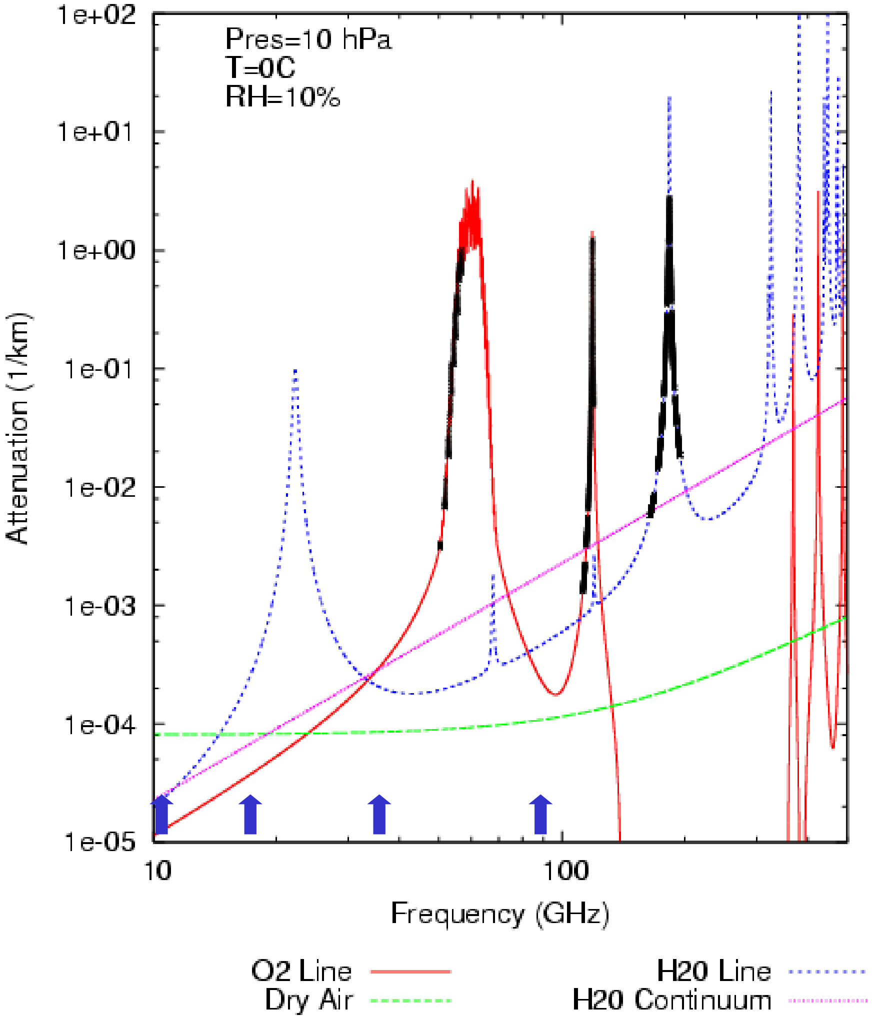
(not to scale)

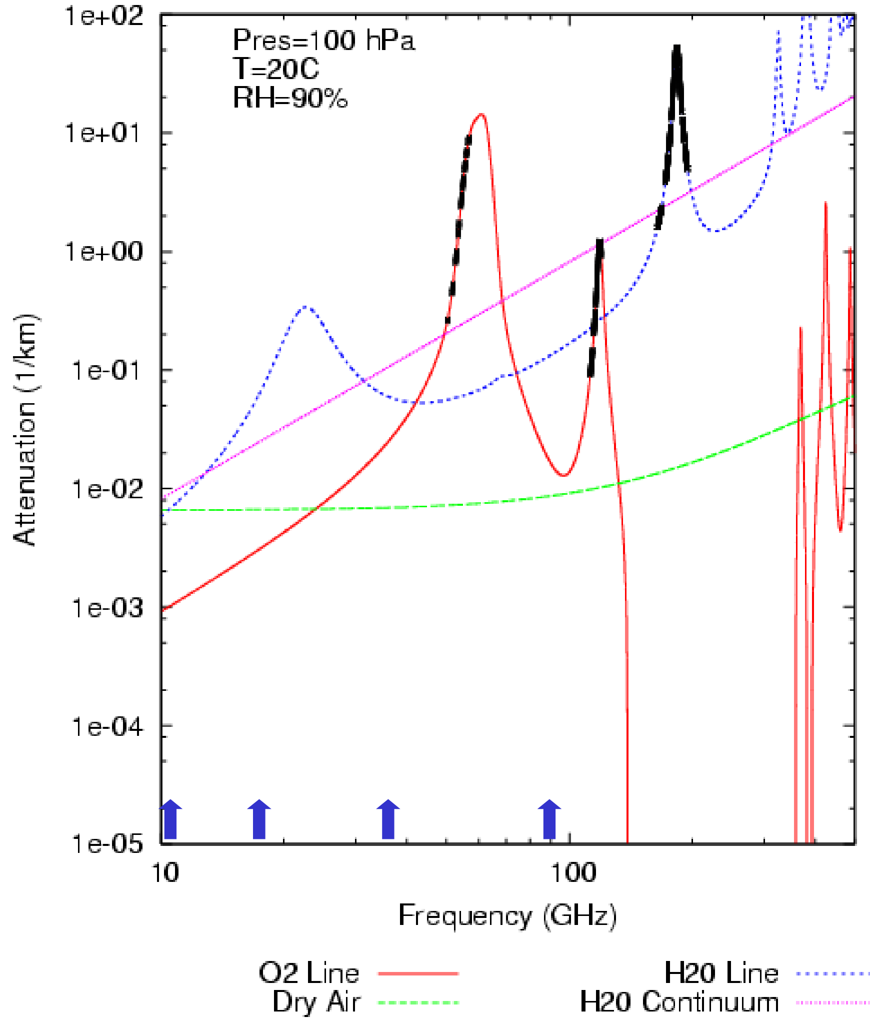
ER-2 Doppler Radar (EDOP)

- X band (9.6 GHz)
  - Minimize attenuation
  - WSR-88D (3.0 GHz)
- Fixed nadir/forward beams
- Resolution
  - 100m horizontal
  - 37.5 m gate spacing
- Accuracy
  - Reflectivity (1 dBZ)
  - Doppler velocity (0.1 m/s)
  - Derived winds
    - U ~(< 0.5 m/s)
    - W ~(1 - 2 m/s)



Absorption and Channel Selection



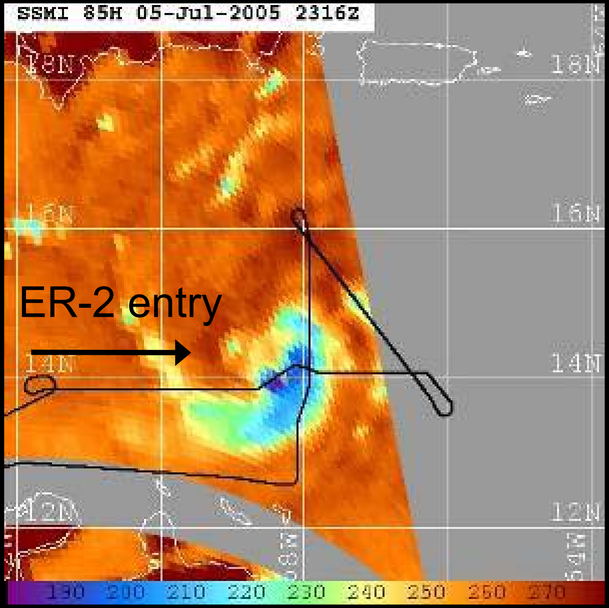


Blue arrows indicate AMPR window channels

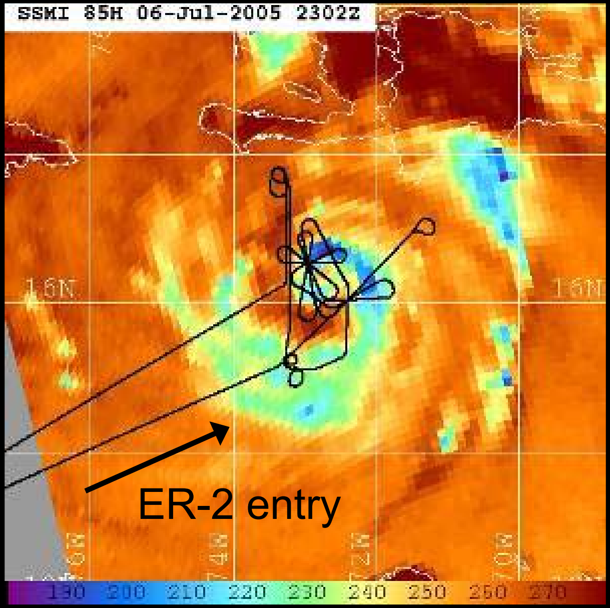
Black spaces indicate HAMSR sounding channels

ER-2 Flight Lines Over Hurricane Dennis

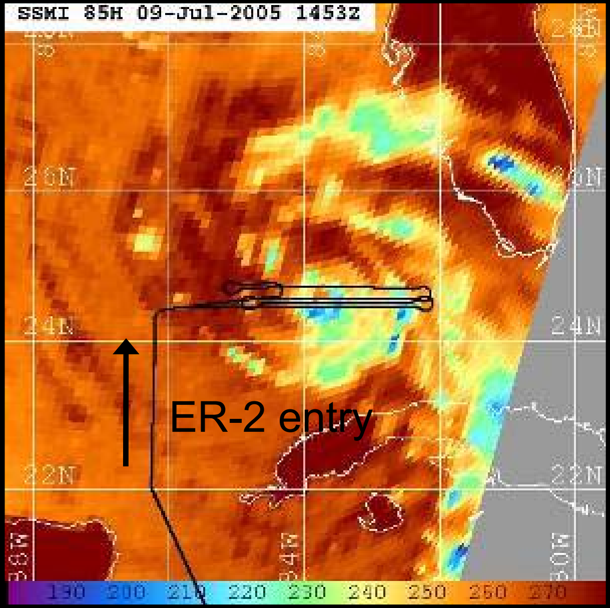
July 5 “Figure-4” Pattern



July 6-7 “Multiple Figure-4” Patterns S of Haiti



July 9 “E-W and W-E” Patterns N of Cuba



Overpass Times (UTC)

1) 2028-2119
2) 2120-2149
3) 2154-2220

Overpass Times

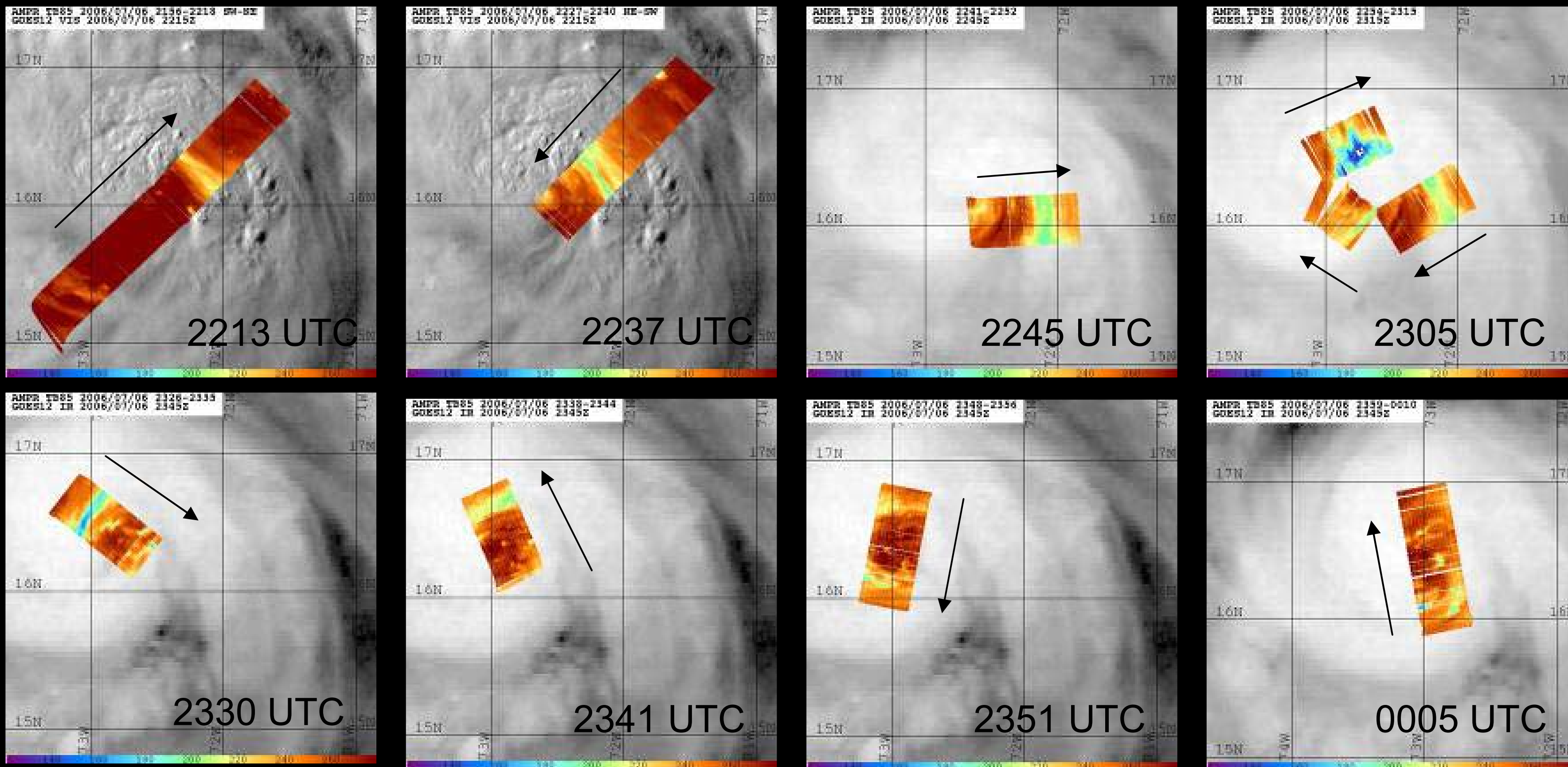
1) 2156-2218
2) 2227-2240
3) 2241-2252
4) 2254-2315
5) 2326-2335
6) 2338-2344
7) 2348-2356
8) 2359-0010
9) 0011-0036
10) 0047-0108
11) 0122-0144

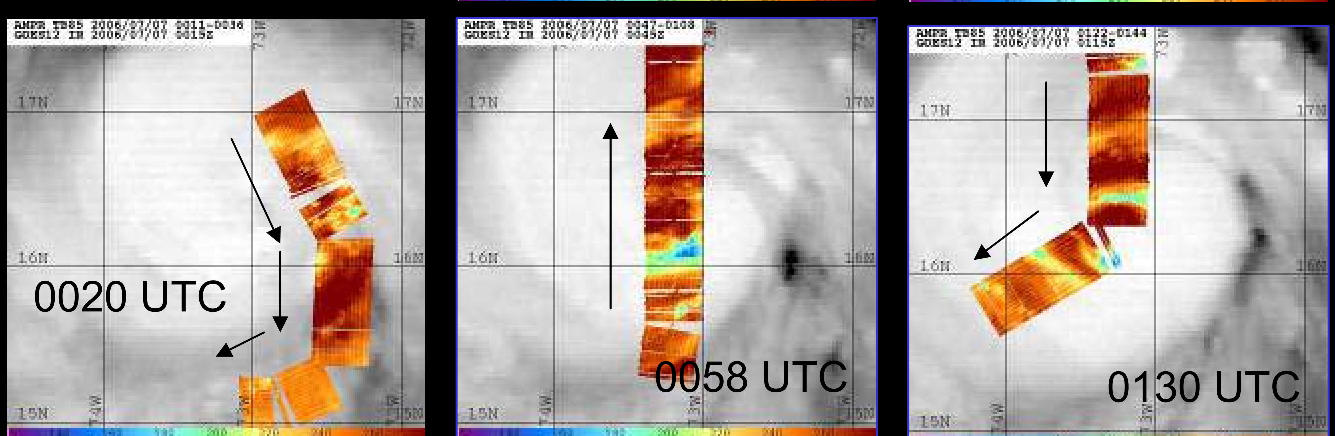
Overpass Times

1) 1334-1351
2) 1359-1414
3) 1420-1440
4) 1446-1503

Scale 180-280K

AMPR 85 GHz Imagery from July 6-7 ER-2 Flight Lines





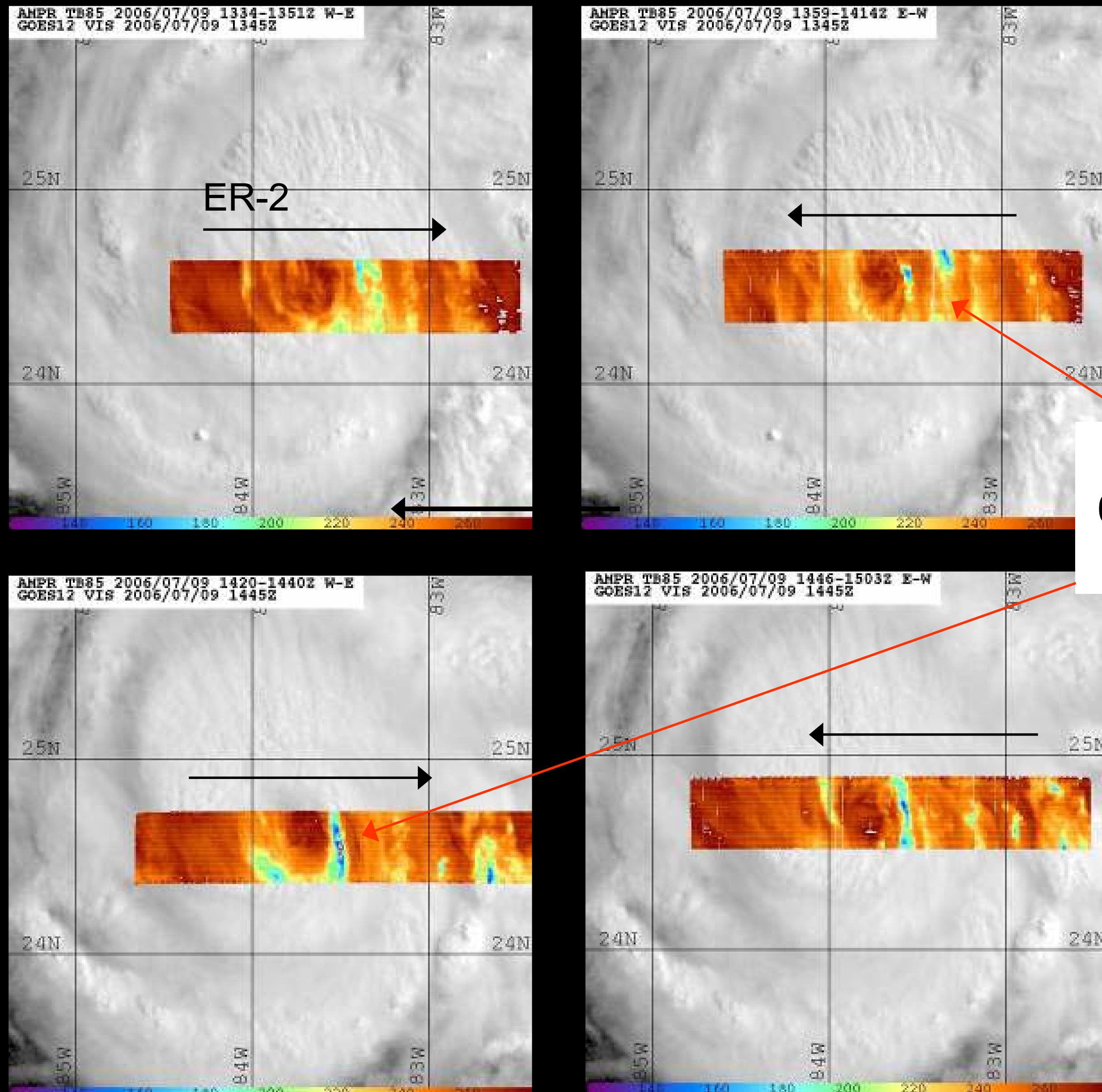
NOAA P-3 was on-station during the last four ER-2 overpasses

Scale 120-280K

AMPR 85 GHz Imagery from July 9 ER-2 Flight Lines

Pass 1
1334-1351

Pass 2
1359-1414



T_B drops by 60K to 120K in 15 minutes

Pass 3
1420-1440

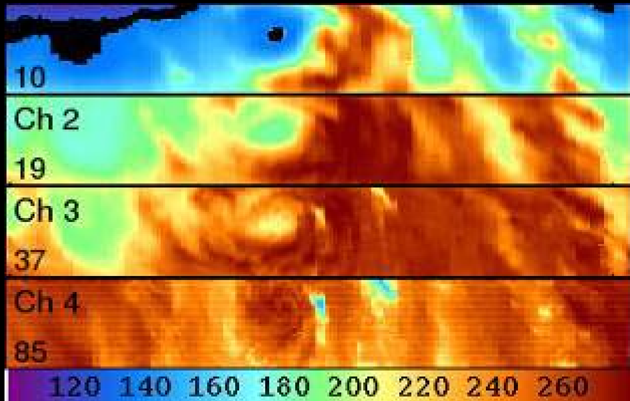
Pass 4
1446-1503

Scale 120-280K

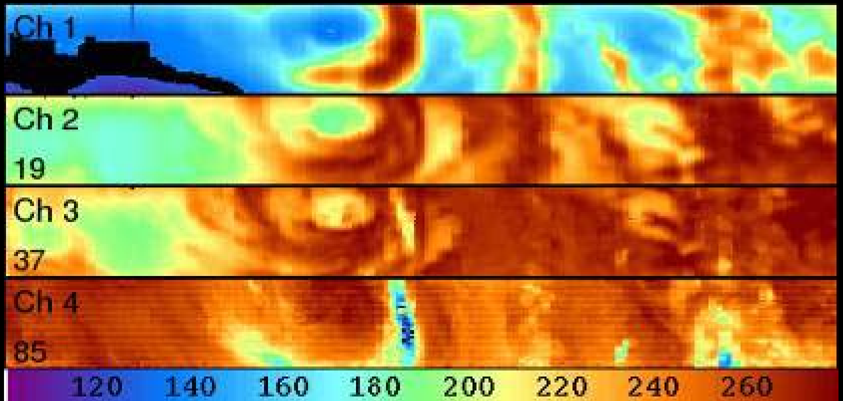
AMPR and EDOP Imagery July 9 Pass 2

22 minutes later

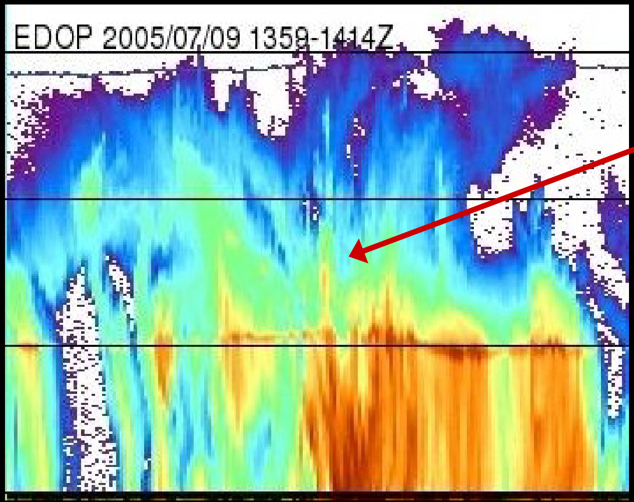
AMPR and EDOP Imagery July 9 Pass 3



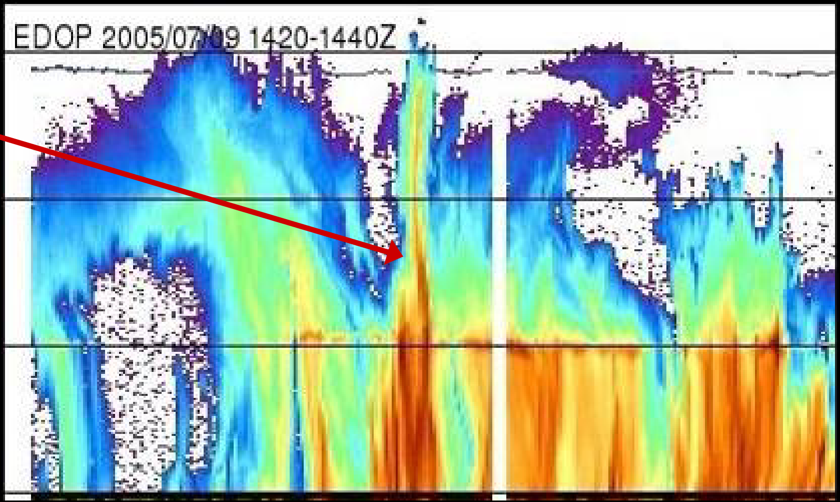
85 GHz T_B near 120 K and a tightening of the the eyewall structure



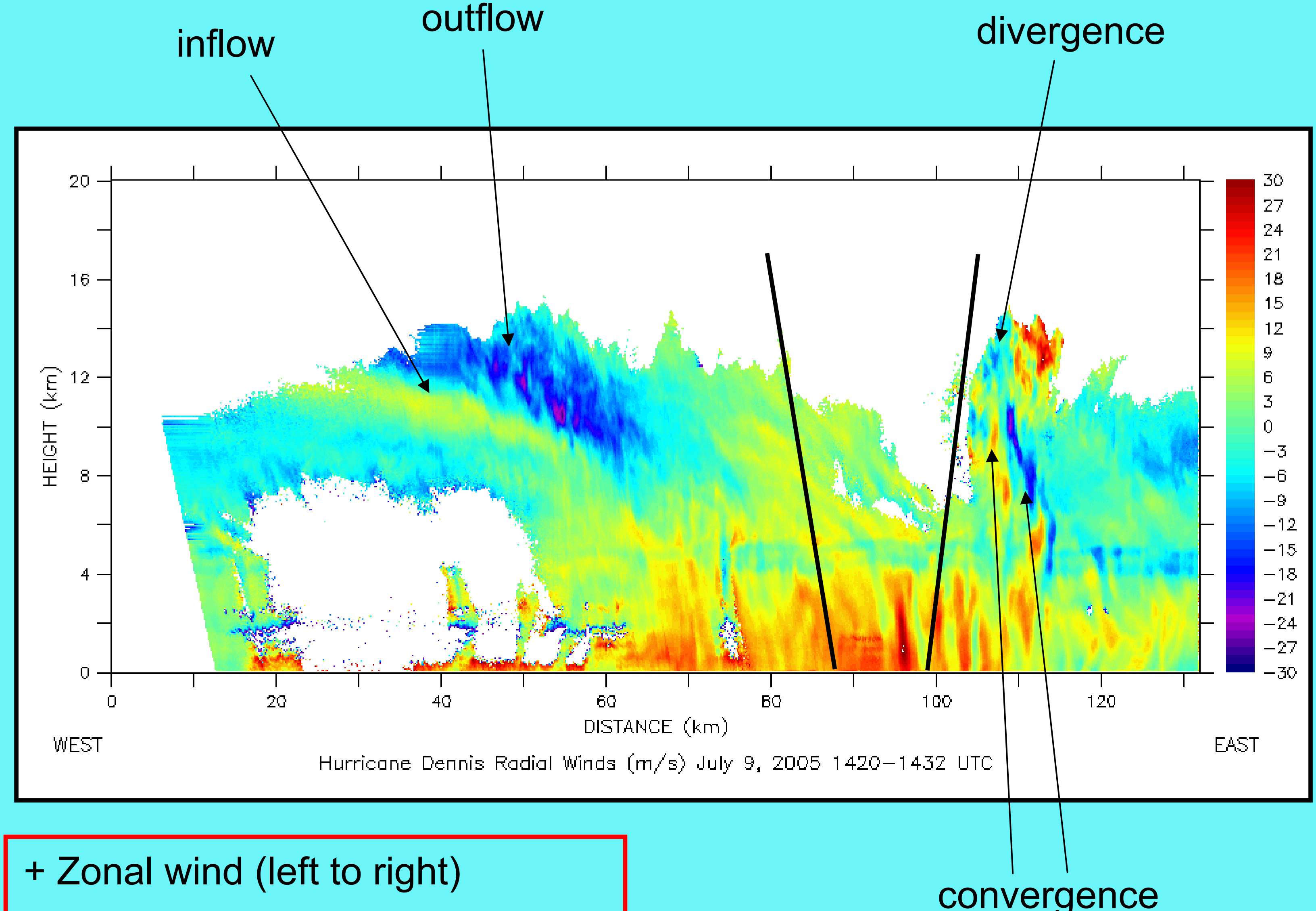
EDOP reflectivity and vertical velocity profiles showed a narrowing, rapidly rising hydrometeor column, suggesting a strengthening vortex fueled by latent heat release



Narrow, rapidly rising convective "hot tower"
30 dBZ column rises 7-km in 22 minutes and the bright band is elevated in the surrounding region



Derived Radial Winds (m/s)



+ Zonal wind (left to right)

- Zonal wind (right to left)

Figure courtesy Steve Guimond, FSU

Derived Vertical Winds (m/s)

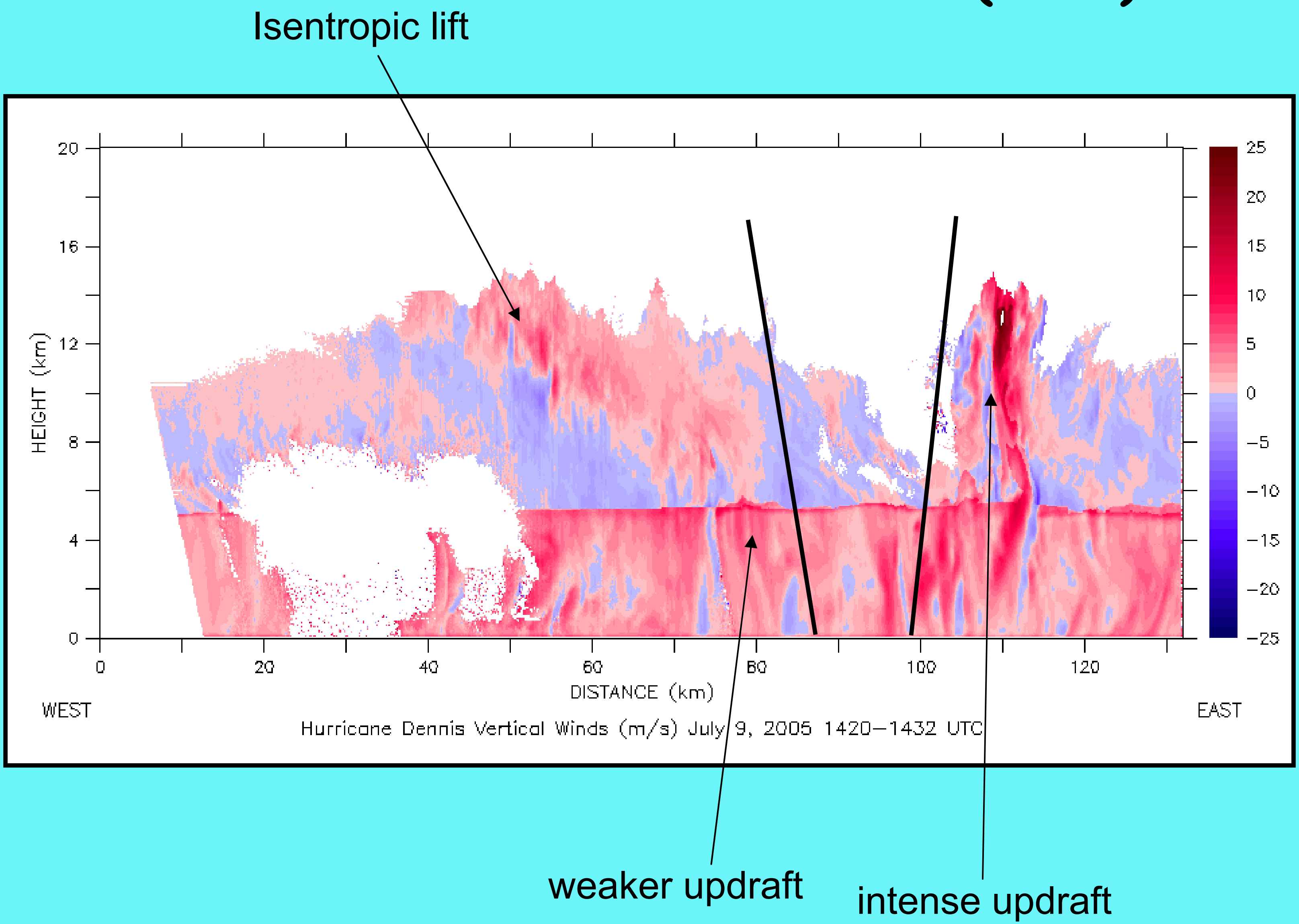
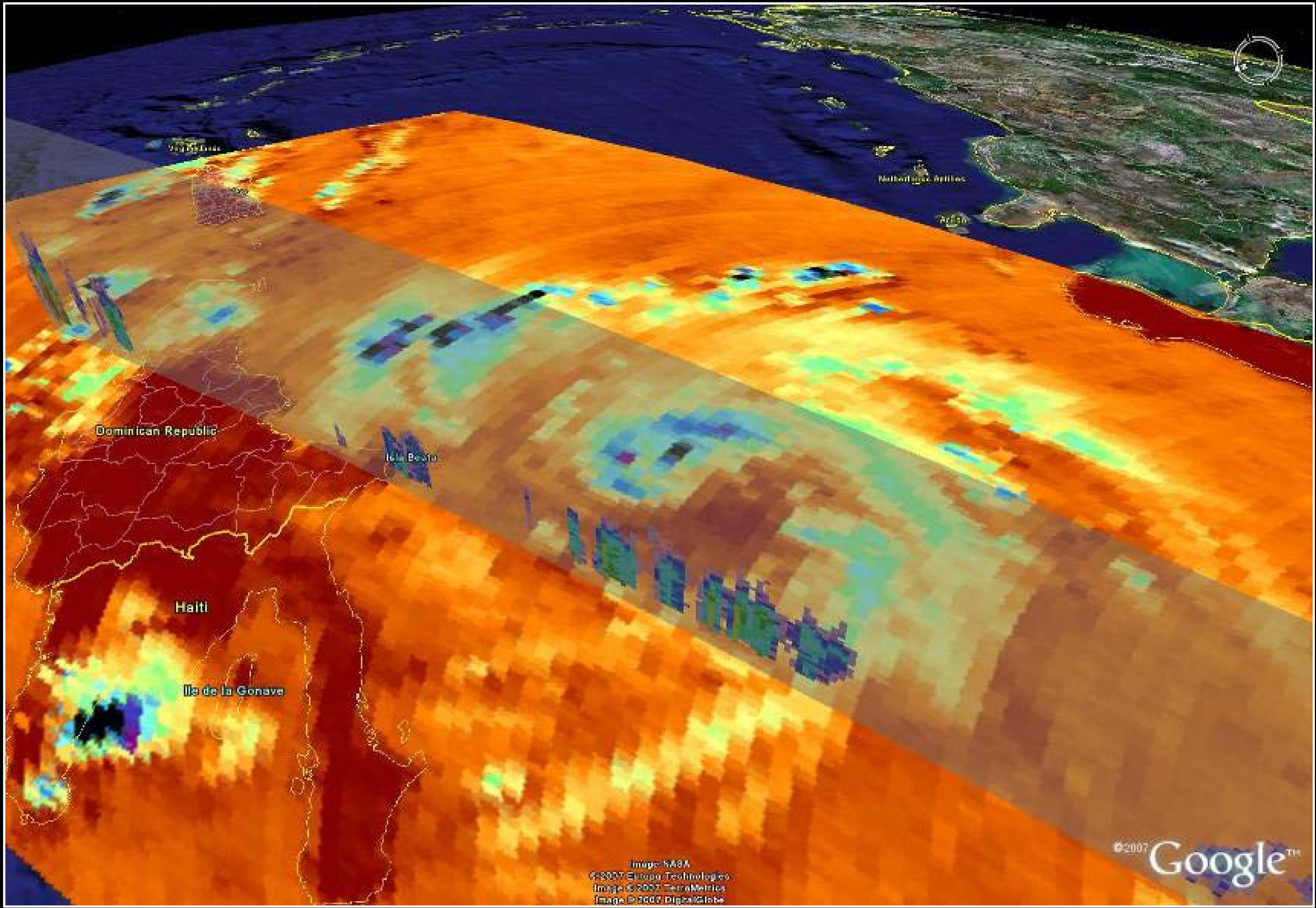


Figure courtesy Steve Guimond, FSU

TRMM PR Cross Sections Near 6 July 2005 ER-2 Overpass of Dennis



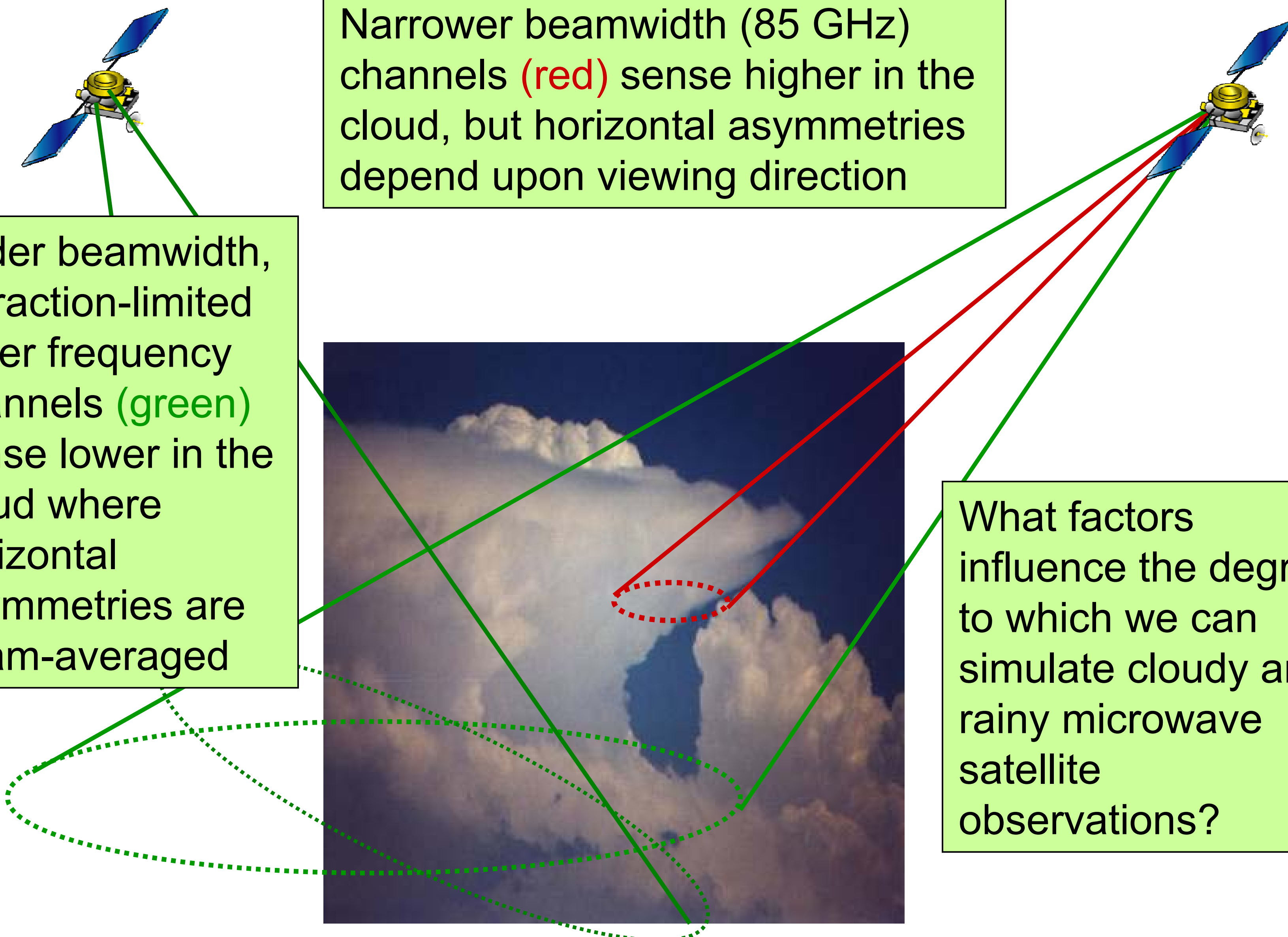
TRMM 2131 UTC   85 GHz background (170-280K)

ascending

COAMPS Simulations
Initialized 12 UTC on July 5

July 7 00 UTC (36 hours)
July 9 18 UTC (102 hours)

Passive Microwave Satellite Observations of Clouds



Narrower beamwidth (85 GHz) channels (red) sense higher in the cloud, but horizontal asymmetries depend upon viewing direction

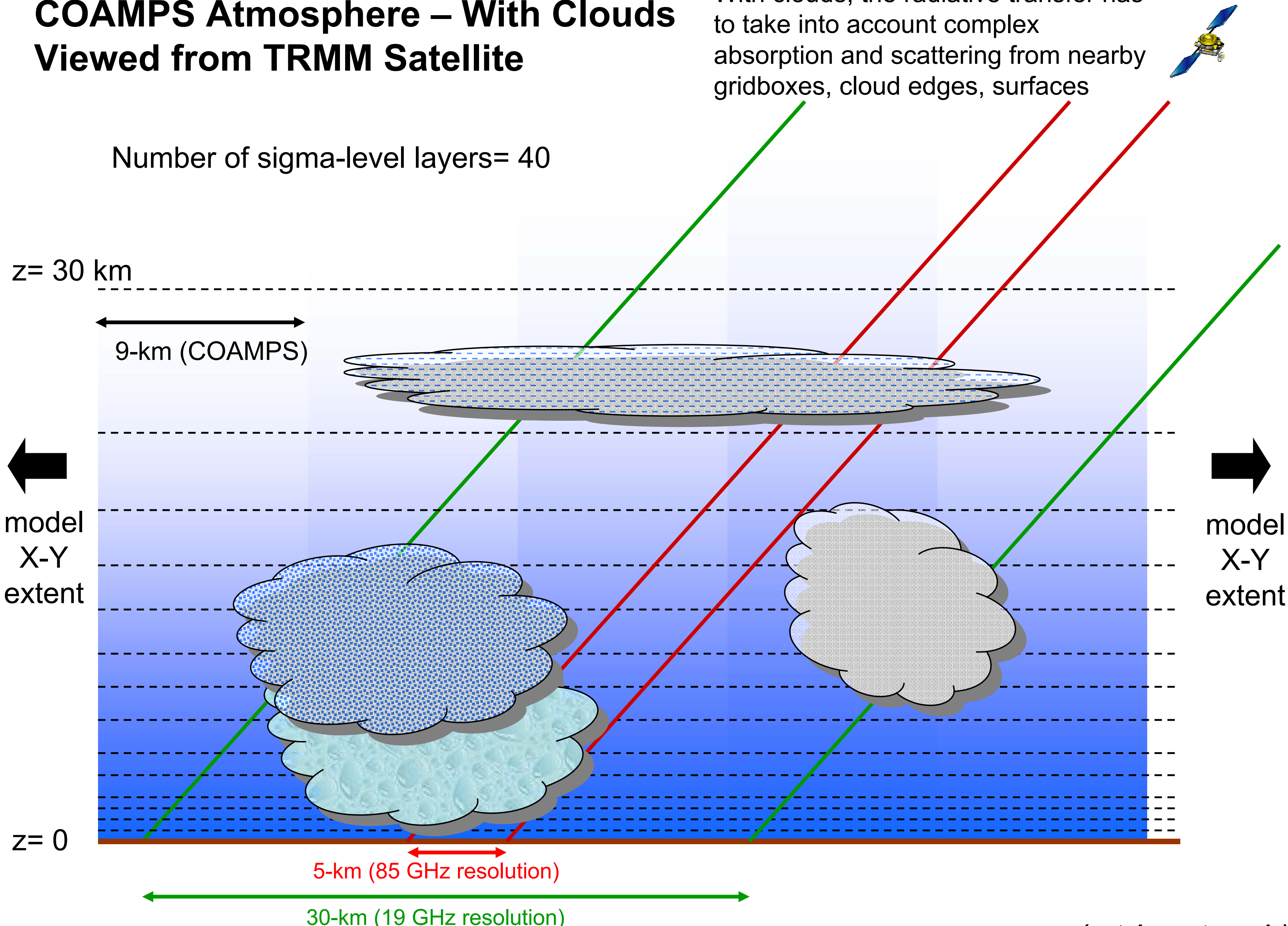
Wider beamwidth, diffraction-limited lower frequency channels (green) sense lower in the cloud where horizontal asymmetries are beam-averaged

What factors influence the degree to which we can simulate cloudy and rainy microwave satellite observations?

(not drawn to scale)

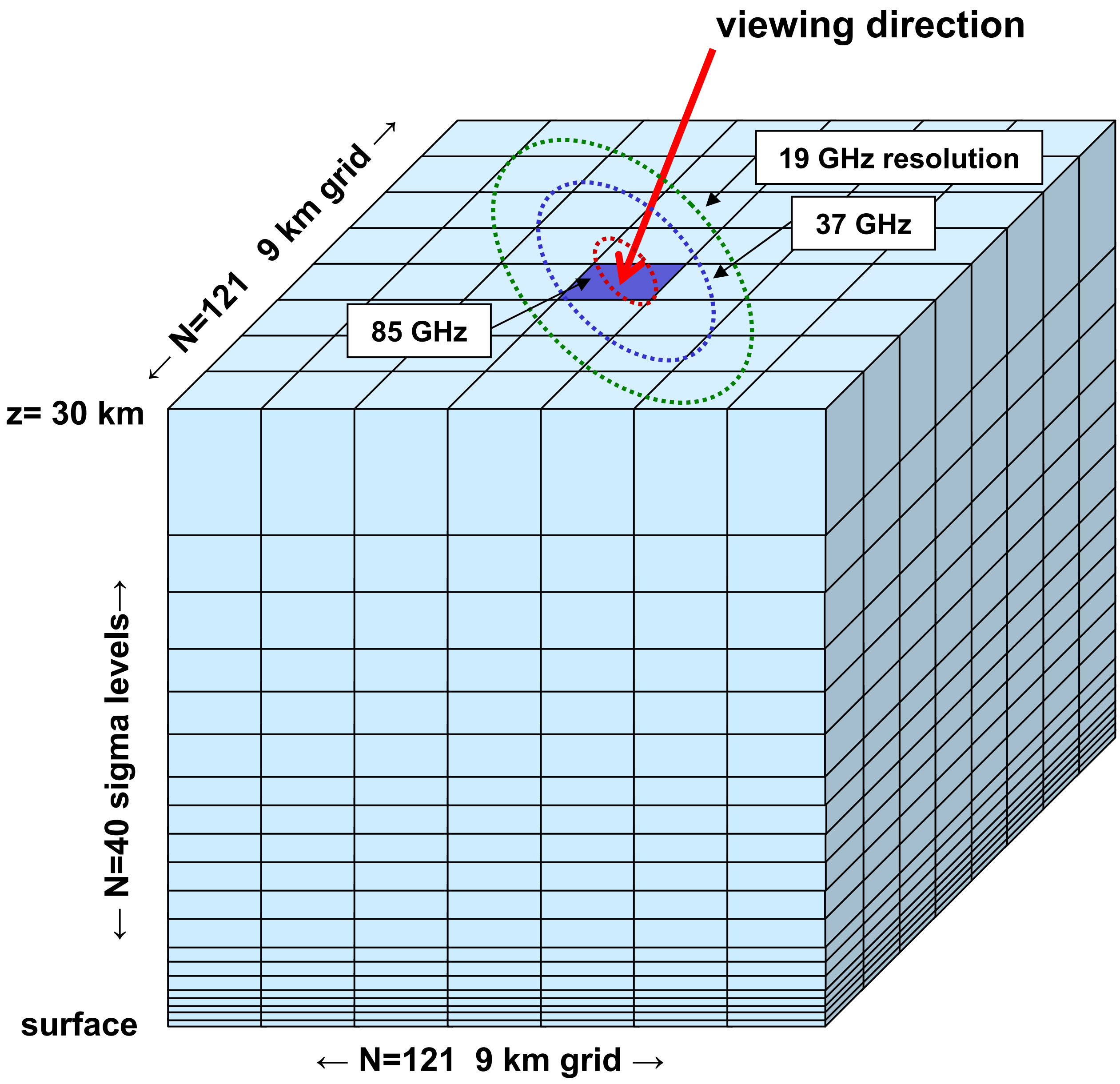
COAMPS Atmosphere – With Clouds Viewed from TRMM Satellite

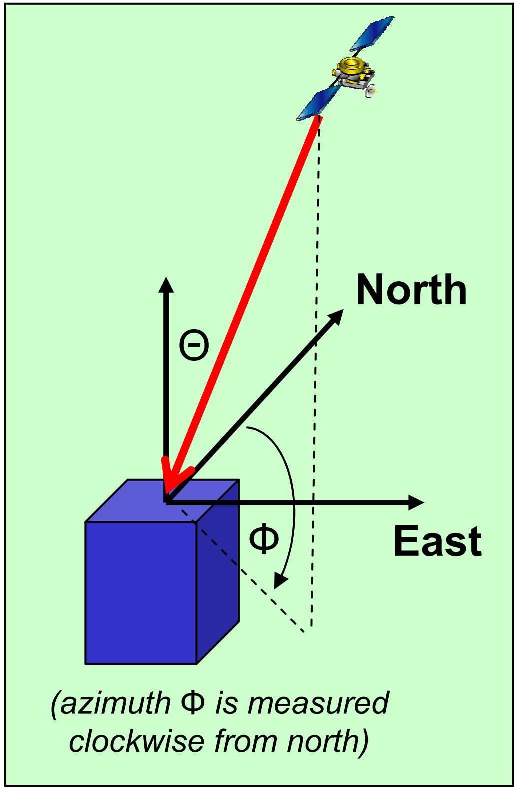
With clouds, the radiative transfer has to take into account complex absorption and scattering from nearby gridboxes, cloud edges, surfaces



(not drawn to scale)

Typical COAMPS 3-D Grid
Viewed from satellite along direction (Θ,Φ)



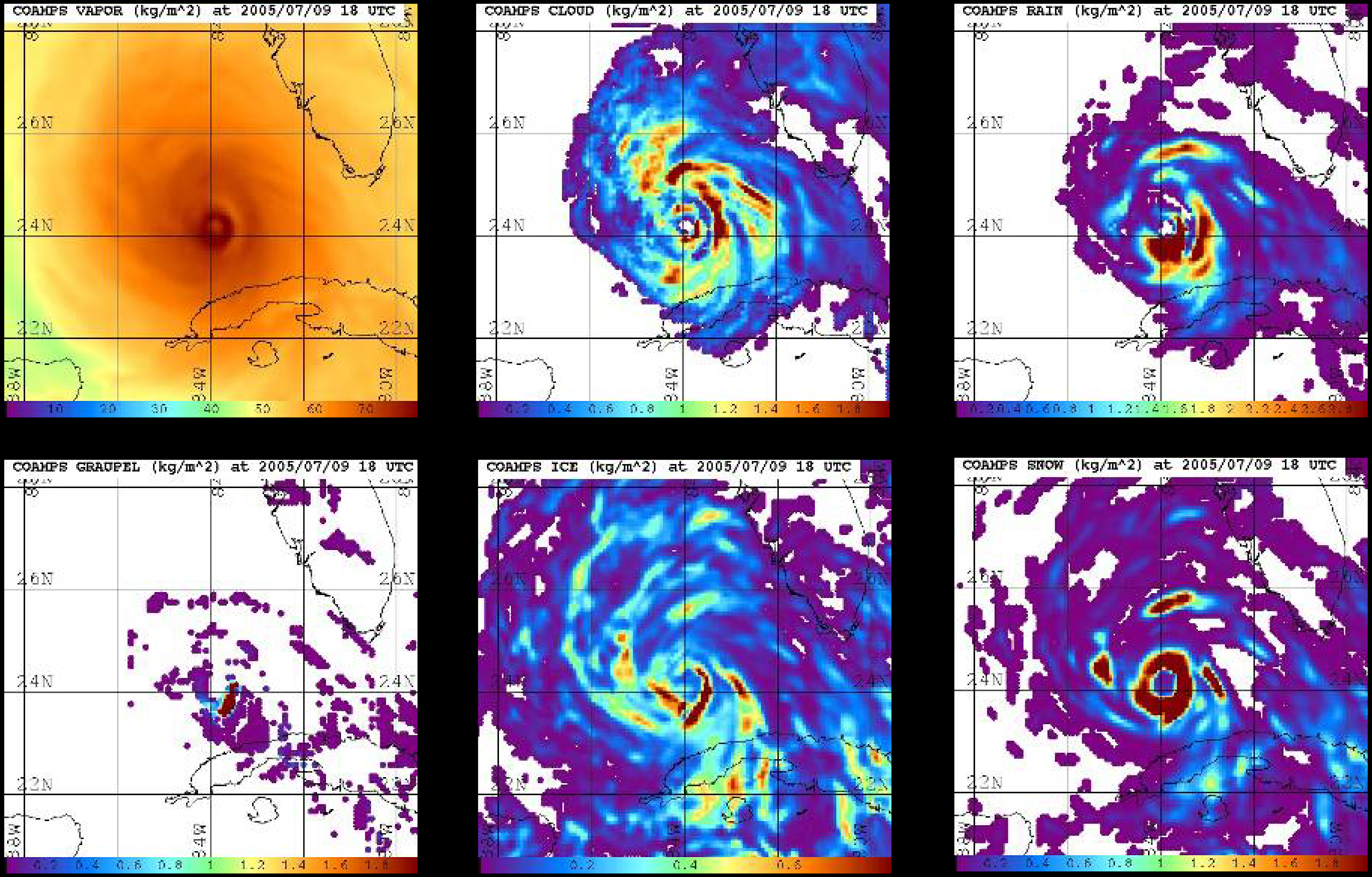


Each "cube" contains one or more mixing ratios from:

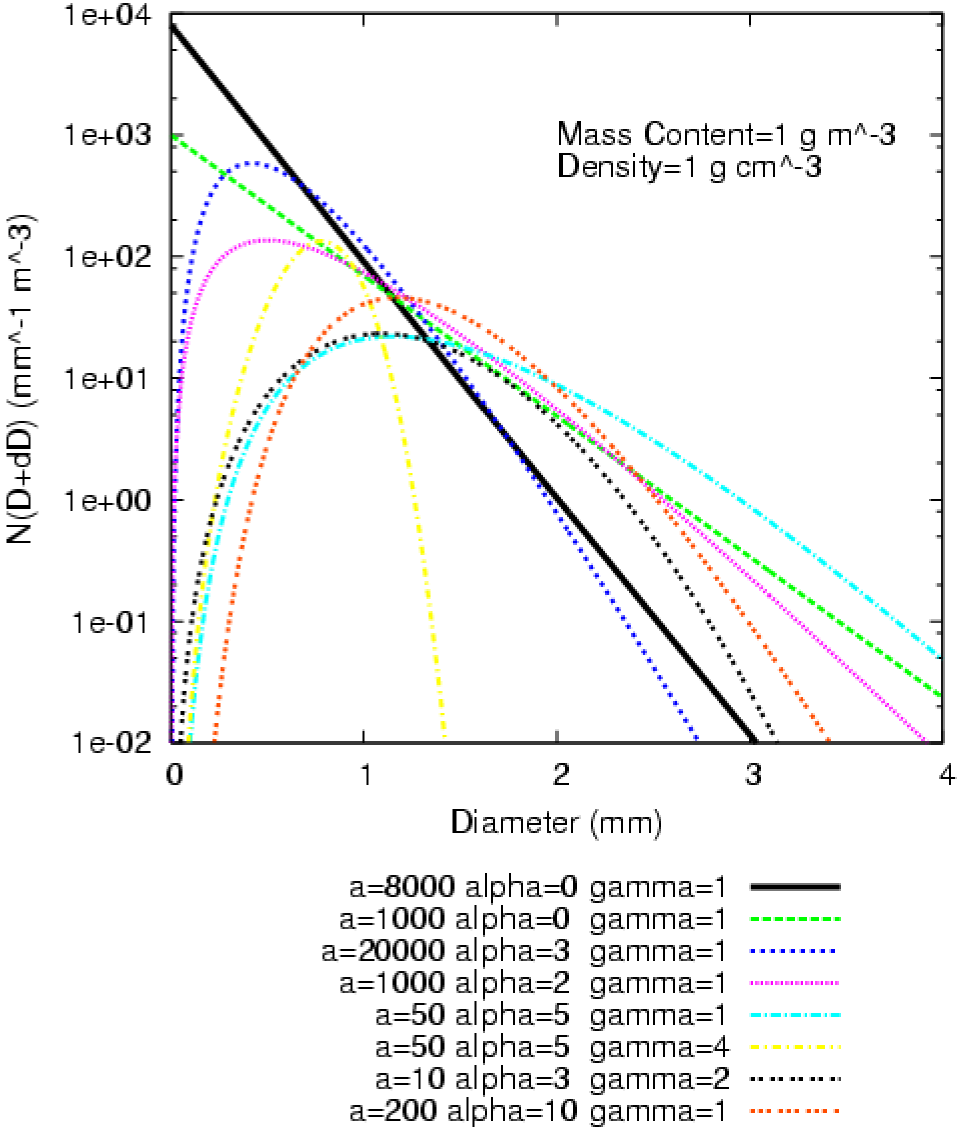
cloud	(C)
rain	(R)
vapor	(V)
ice	(I)
graupel	(G)
snow	(S)

(not drawn to scale)

COAMPS Columnar Mass Contents   July 9 2005 18 UTC (102 hours)



Microphysical and modeling assumptions



Many size distribution parameters can be fit for a given mixing ratio in single moment physics schemes

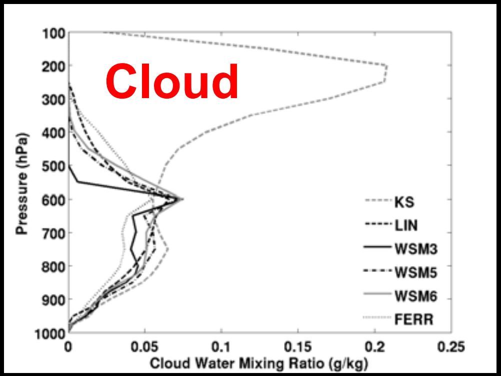
Deirmendjian (1969) modified gamma drop size distribution (DSD):
$N(D) = a\,D^{\alpha} \exp(-bD^{\gamma})$

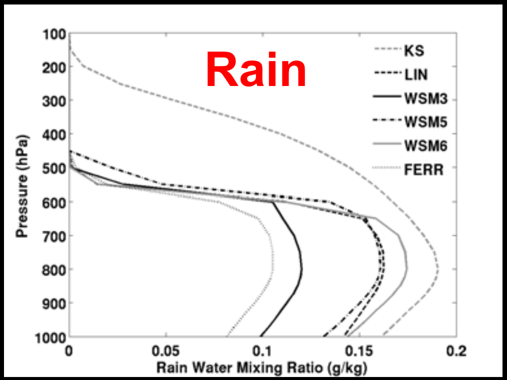
Gamma: $\gamma=1$
Exponential: $\alpha= 0$ $\gamma=1$
Marshall Palmer (1948): Exponential with $a=8000\ mm^{-1}\ m^{-3}$ $b=4.1\ R^{-0.21}$

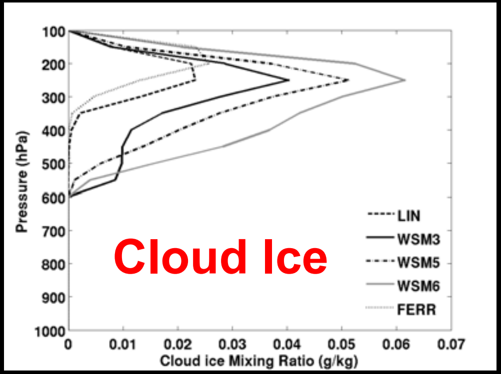
What is an appropriate DSD and particle density for cloud, graupel, ice, and snow?

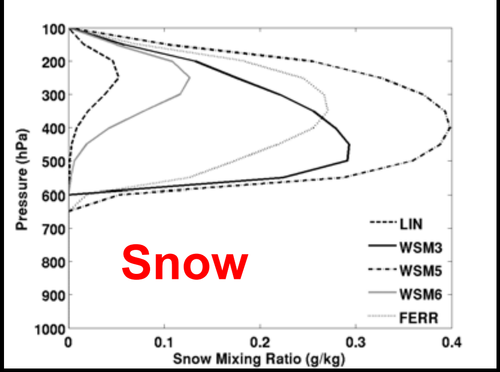
A large contribution to forward modeling error

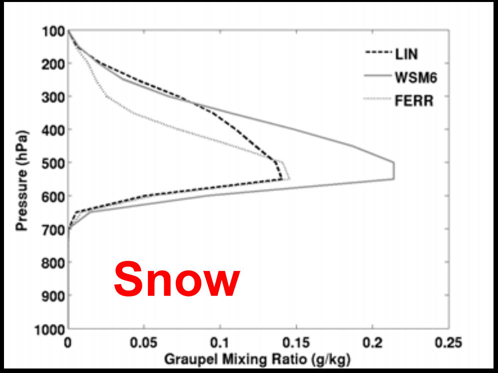
Microphysical sensitivity studies (Li and Pu, 2007)

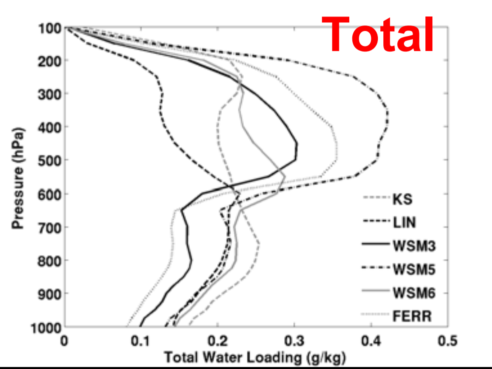










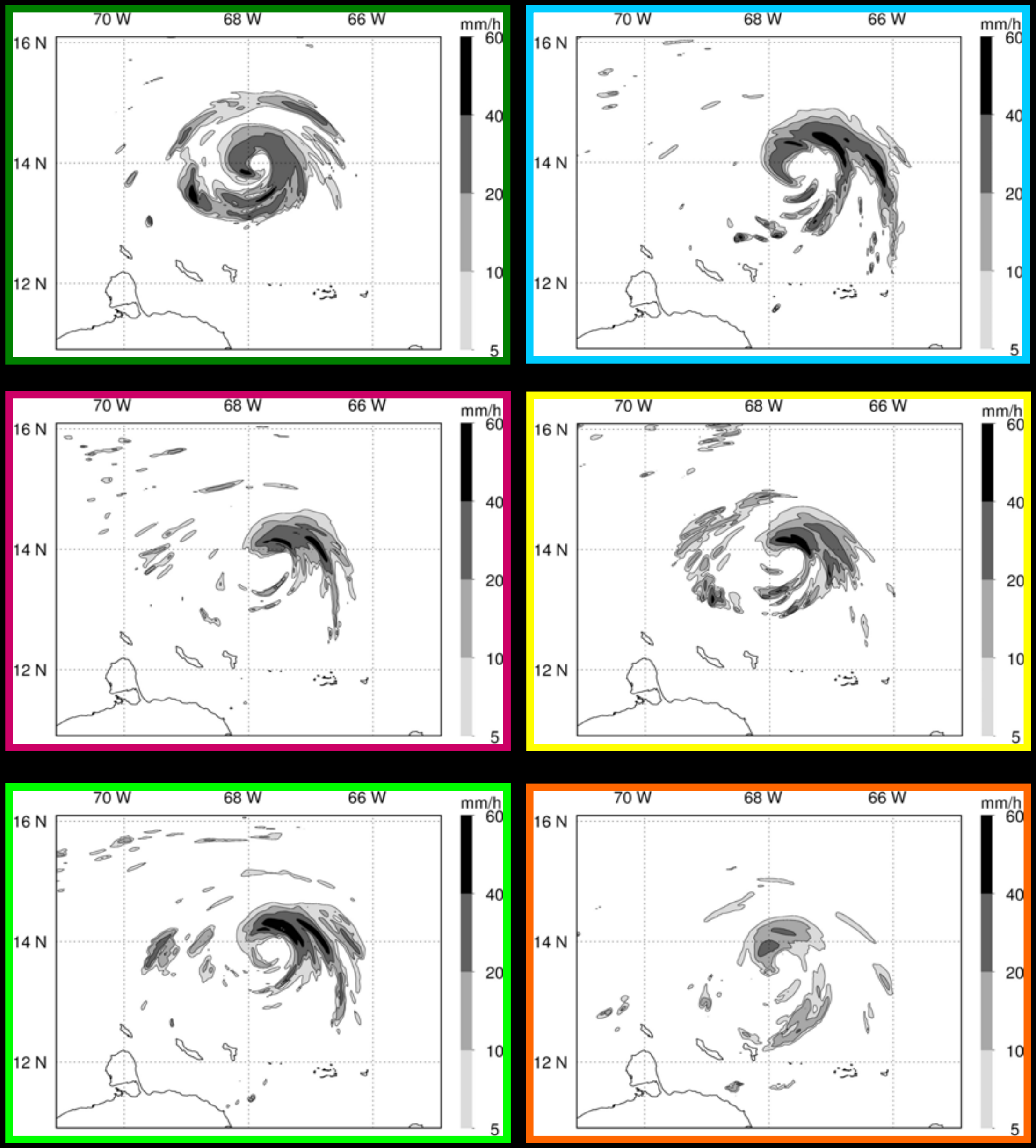


Vertical distributions of area averaged mixing ratios in g kg^{-1} (within 250-km radius from the storm center)

Hurricane Emily simulation
0600 UTC 15 July 2005

KS: Kessler 3-class warm rain (no ice)
LIN: 6-class single moment
WSM3: WRF 3-class single moment
WSM5: WRF 5-class single moment
WSM6: WRF 6-class single moment
FERR: Ferrier vapor/total condensate

Microphysical sensitivity studies (Li and Pu, 2007)



Hourly rainfall at same time step

Hurricane Emily simulation
0600 UTC 15 July 2005

KS: Kessler 3-class warm rain (no ice)
LIN: 6-class single moment
WSM3: WRF 3-class single moment
WSM5: WRF 5-class single moment
WSM6: WRF 6-class single moment
FERR: Ferrier cloud/condensate

Spectral Habit Ice Prediction System (SHIPS)

(Hashino and Tripoli, 2007)

12 prognostic variables per a bin

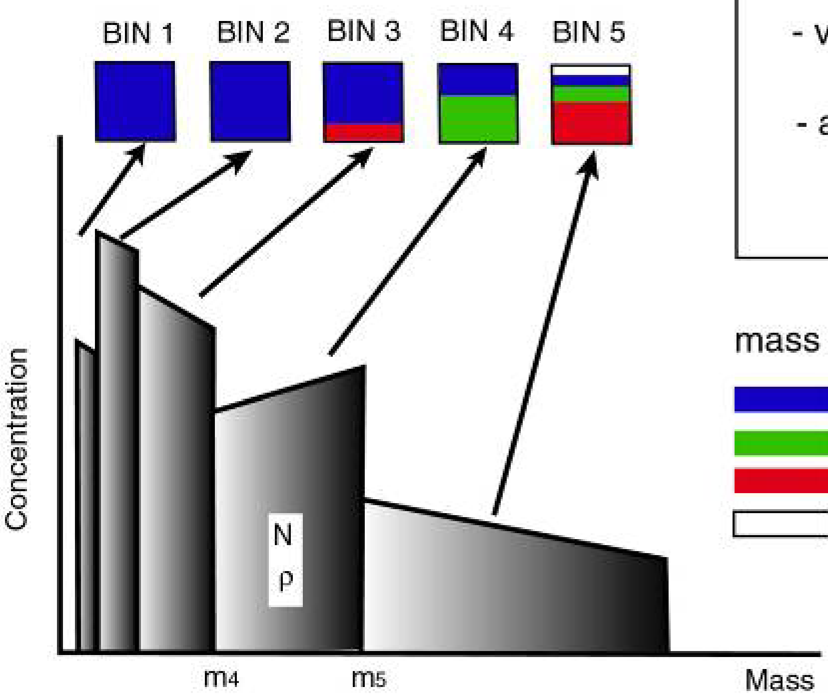
two moments of sub-distribution

- mass content, ρ
- concentration, N

+

particle property variables (PPVs)

- growth mass content components
  - ice crystal mass
  - rime mass
- lengths variable components
  - a-axis length
  - c-axis length
  - dendritic arm length
  - bullet rosette length
  - irregular crystal length
- volume variable components
  - circumscribing volume
- aerosol mass content components
  - aerosol total mass
  - aerosol soluble mass



mass content components

- ice crystal mass, m_i
- aggregate mass, m_A
- rime mass, m_R
- melt-water mass, m_W

PPVs

- Integrated based on local conditions and history of particles
- Each bin has different properties of ice particles.
- The properties change in time and space.

No use of categorization!

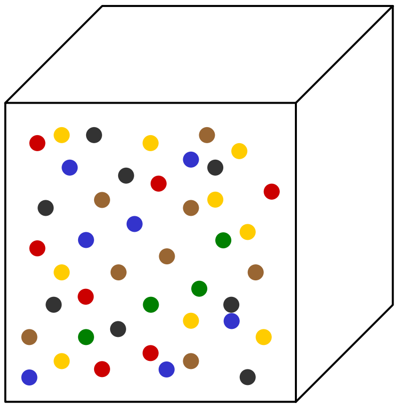
↕

Bin model
Bulk micro. par.

Outputs of SHIPS

- Concentration, mass content, and Particle Property Variables (PPVs) for a bin.
- Habit of ice crystals and type of solid hydrometeors in the bin can be diagnosed with PPVs.
- Predicted maximum dimension, circumscribing volume, aspect ratio, bulk density of solid hydrometeors.
- Aerosol distribution outside and inside hydrometeors, and solubility of the aerosols.

Microphysical and modeling assumptions



Six colors representing size distribution of each specie inside each gridbox

Exponential distribution assumed for all species

$N(D) = a \exp(-bD)$ (Knowing M, fix a and solve for b)

For clouds, $D \ll \lambda$ and $k_e \sim$ mass content M

Density ($g\ cm^{-3}$) = 0.4 (graupel), 0.1 (snow), 0.9 (ice)

Extinction k_e, albedo ω_0, asymmetry factor g and radar reflectivity η computed for each specie

Total extinction, albedo, asymmetry factor and radar reflectivity are weighted over all six species (i=1,6)

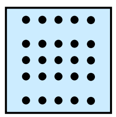
$$<k_e> = \Sigma\, k_{e,i}$$
$$<\omega> = \Sigma\, \omega_i k_{e,i} \,/\, \Sigma\, k_{e,i}$$
$$<g> = \Sigma\, g_i \omega_i k_{e,i} \,/\, \Sigma\, \omega_i k_{e,I}$$
$$<\eta> = \Sigma\, \eta_i$$

In the microwave, $T_B \sim$ physical temperature T

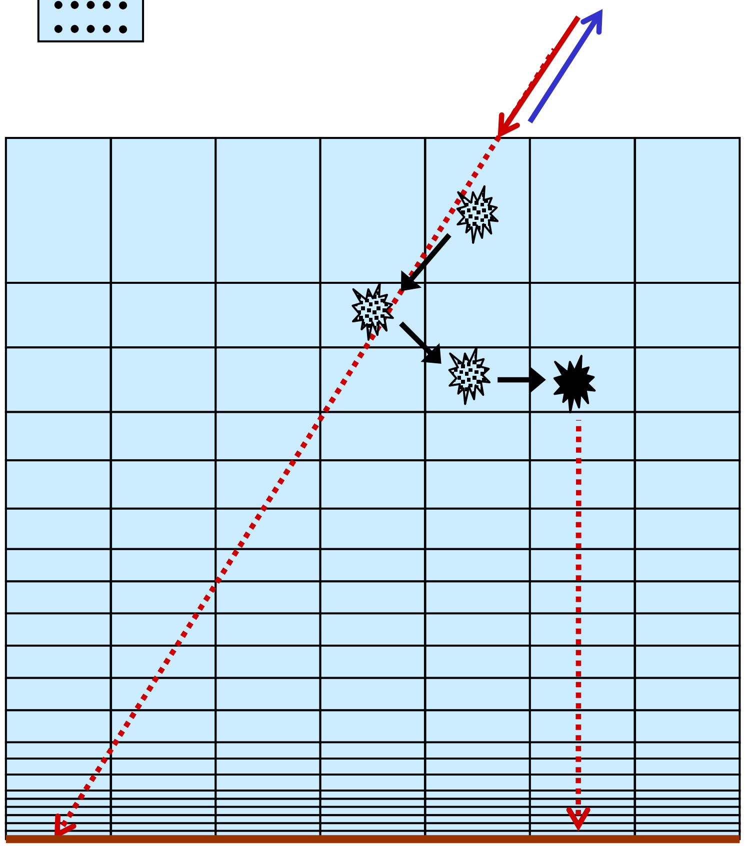
Wind-roughened ocean surface emissivity model (Petty and Katsaros, 1994)

2-D slice of COAMPS Grid Along Arbitrary Viewing Direction (Θ,Φ)
Reverse Monte Carlo (Roberti et. al, 1994)

Top view of gridbox
N computational
points



At each
computational point,
release M photons
opposite viewing
direction



Earth projection
point

Radiative interaction
point

distance to collision= $-\ln(r)/k_{ext}$ r= rand(0,1)

r > (albedo at collision) → absorption event
photon emitted at physical temperature T

r < (albedo at collision) → scattering event
Cosine of scattering angle assumed Henyey-Greenstein and symmetric in azimuth:

$$\mu = \{1 + g^2 - [(1 - g^2)/g(2r - 1) + 1]^2\} / 2g$$

If collision is with the surface (emissivity ε):
r > ε → photon is scattered from μ to -μ (water)
randomly (land)
r < ε → photon is absorbed

Upwelling T_B in the viewing direction for each (i,j) is a simple summation

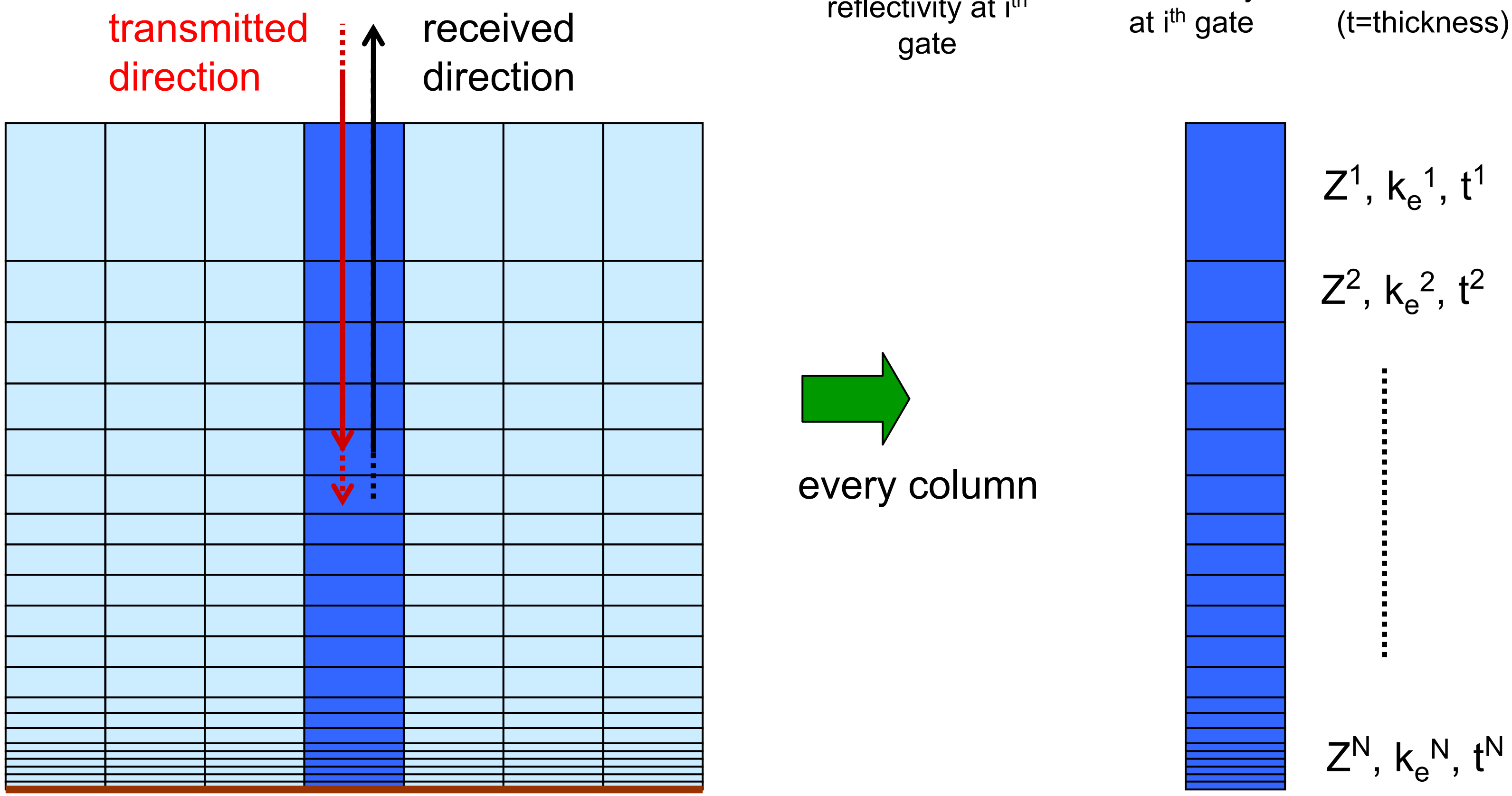
$$T_B(i,j) = \frac{1}{N}\frac{1}{M}\sum_{m=1}^{M}\sum_{n=1}^{N} T_B(n,m)$$

(not drawn to scale)

2-D slice of COAMPS Grid Along Nadir Viewing Direction
Nadir Radar Simulations

$$Z^{i} = \frac{\lambda^{4}}{\pi^{5}|K|^{2}}\eta^{i} \longrightarrow Z^{ic} = Z^{i} - 2\underbrace{\sum_{i=1}^{N} k_{e}^{i} t^{i}}$$

attenuation corrected reflectivity at ith gate = intrinsic reflectivity at ith gate - 2-way path attenuation (t=thickness)

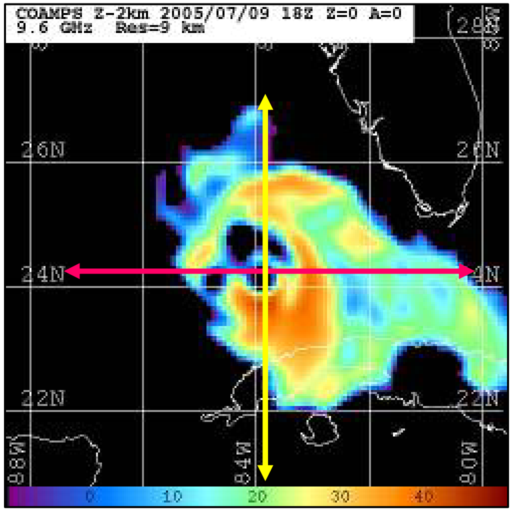


Earth projection point

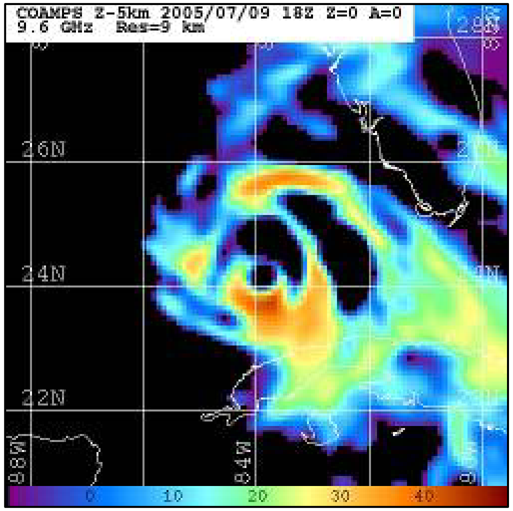
(not drawn to scale)

EDOP and Model-Simulated Radar Imagery 9 July 2005

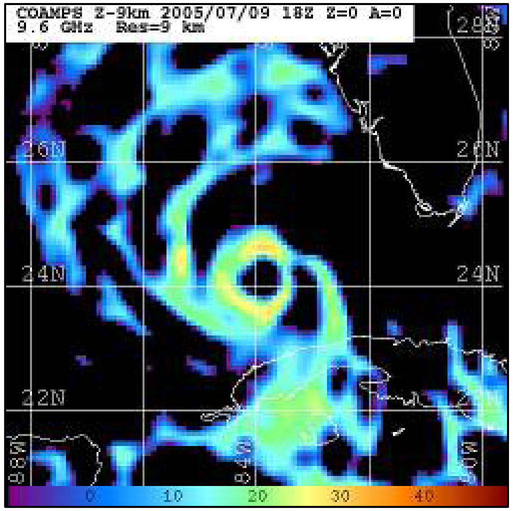
2-km CAPPI

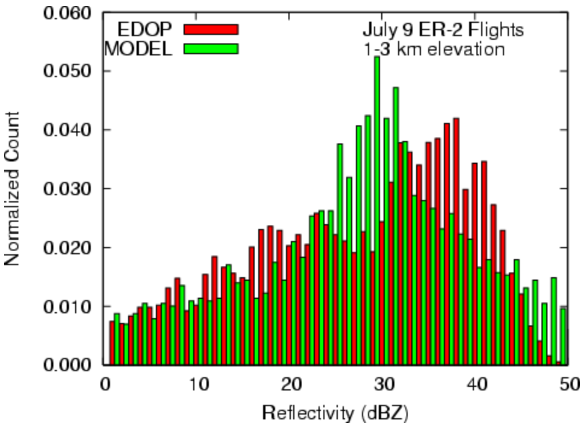


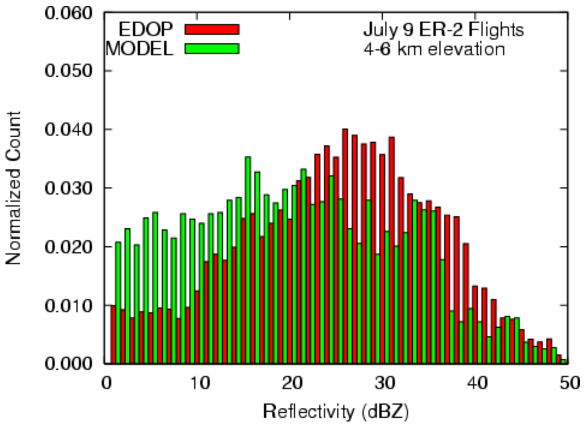
5-km CAPPI

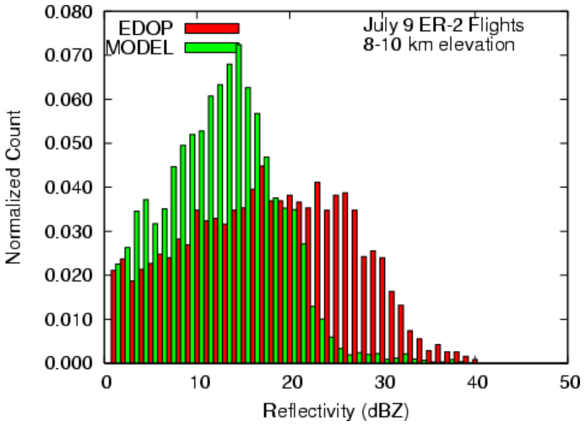


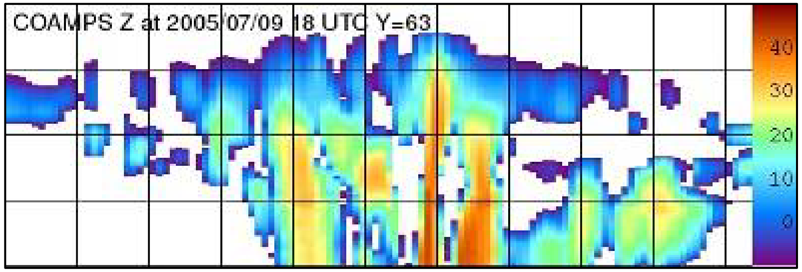
9-km CAPPI











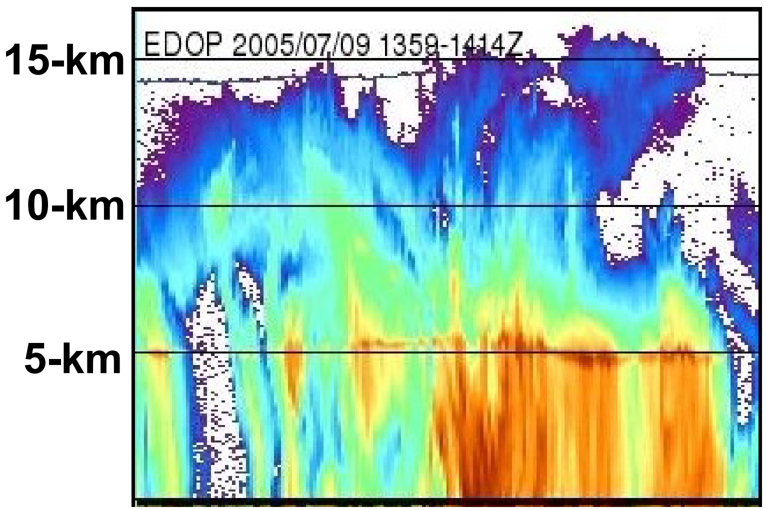
Vertical radar cross section along red line shown above

Comparisons between Radar (EDOP, PR) and Model-Simulated Radar *Cumulative Contoured Frequency By Altitude Diagram (CCFAD)*

Factors to take into account

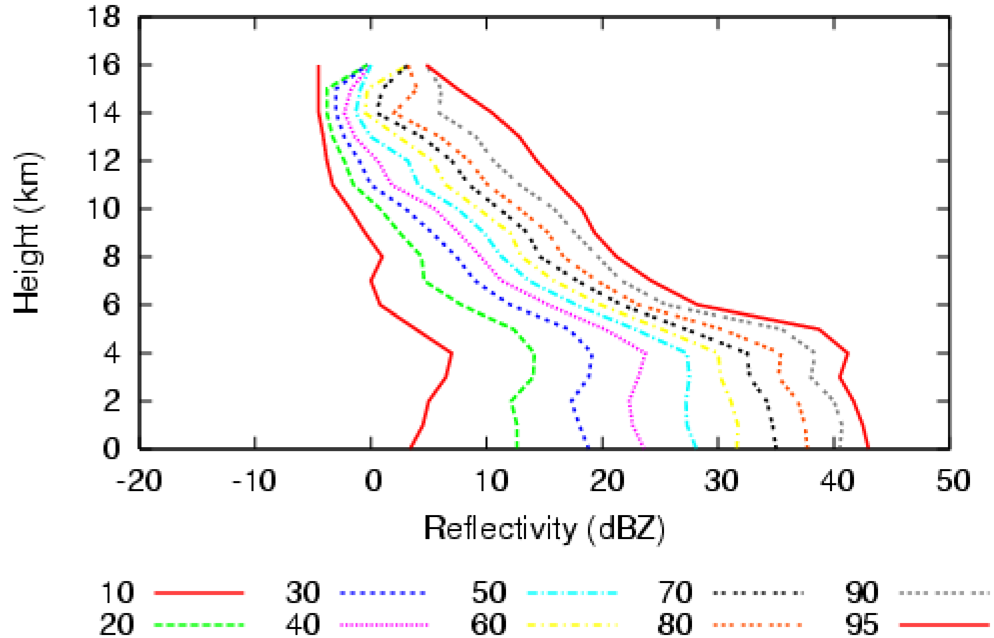
- Minimum detectable reflectivity for EDOP is -5 dBZ, for TRMM is 18 dBZ
- Attenuation in radar observations
- Radar range gates nearest the surface often contain surface contributions
- Radar and model vertical spacings are different

15-min EDOP Radar Profile



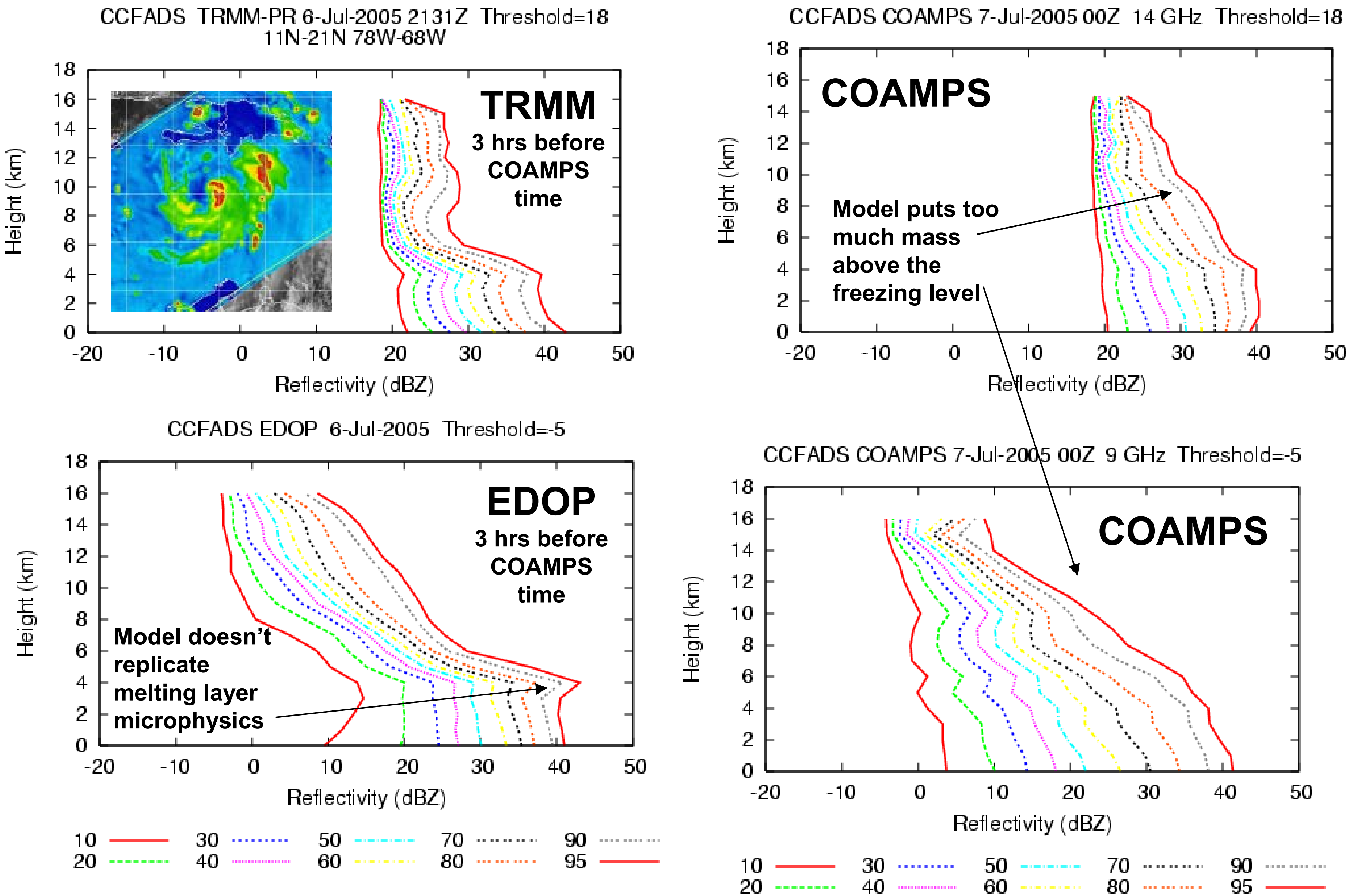
Create CDF of Z at discrete vertical levels

Equivalent CCFAD



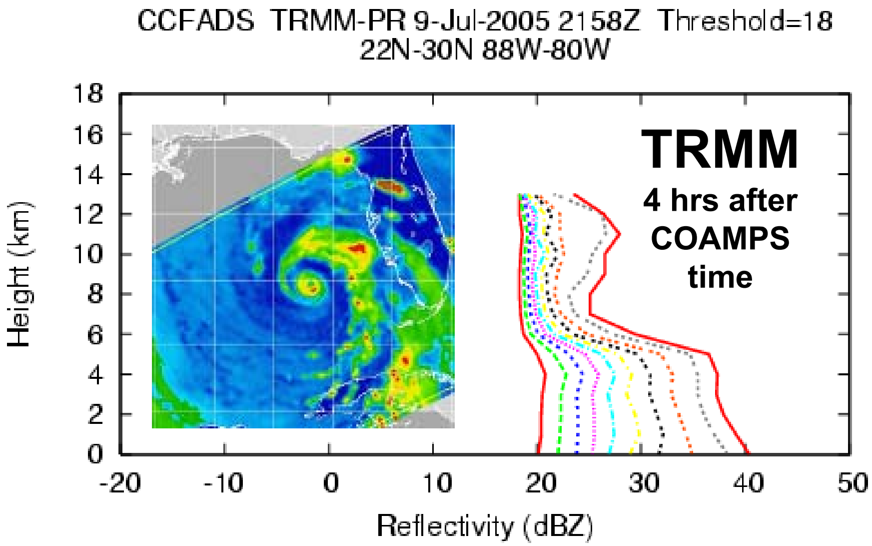
(Contour values in percent)

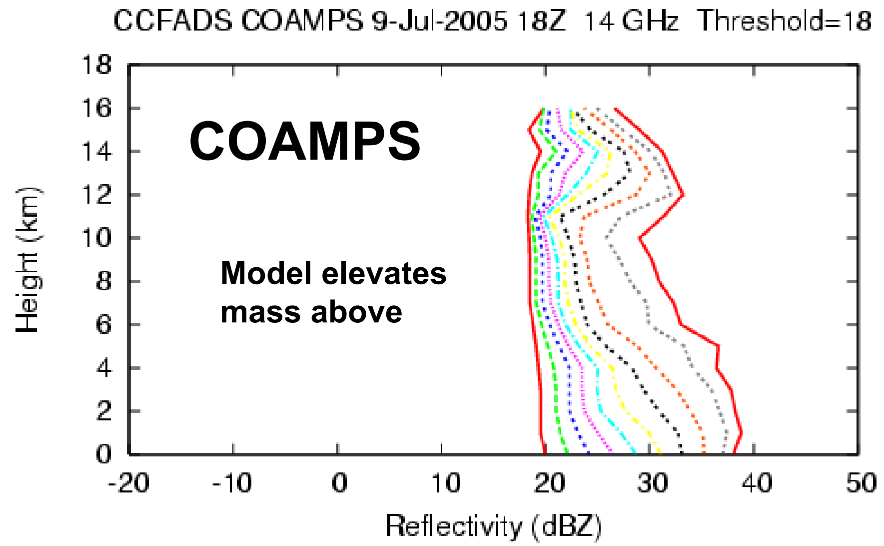
TRMM-PR, EDOP and Model-Simulated CCFADs   6 July 2005

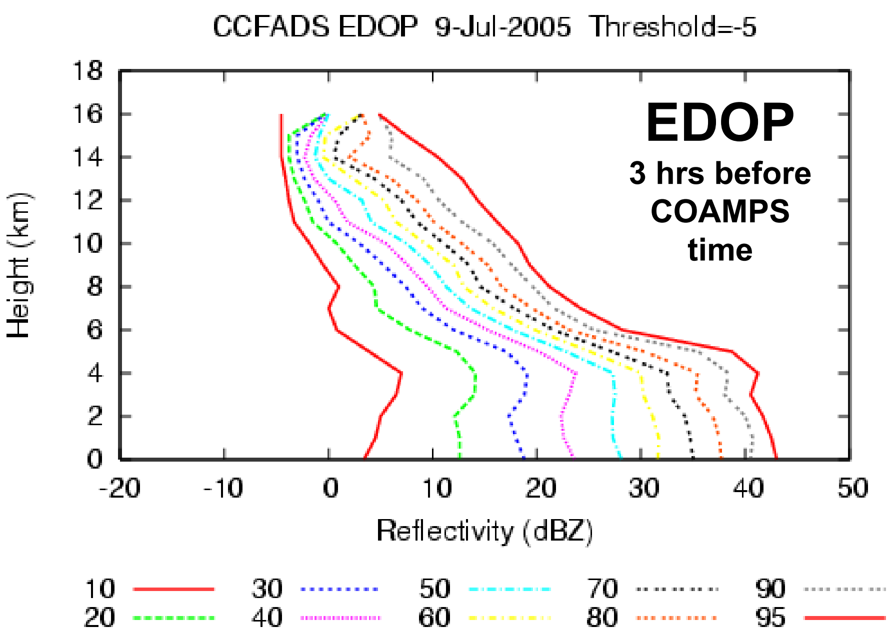


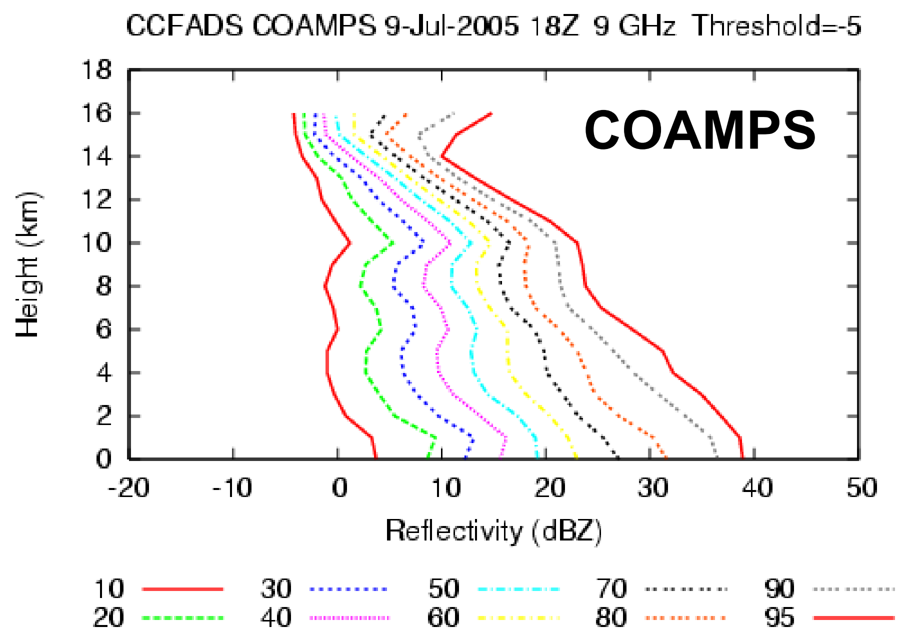
ER-2 flights were near the time of the second (2131 UTC) TRMM overpass

TRMM-PR, EDOP and Model-Simulated CCFADs 9 July 2005



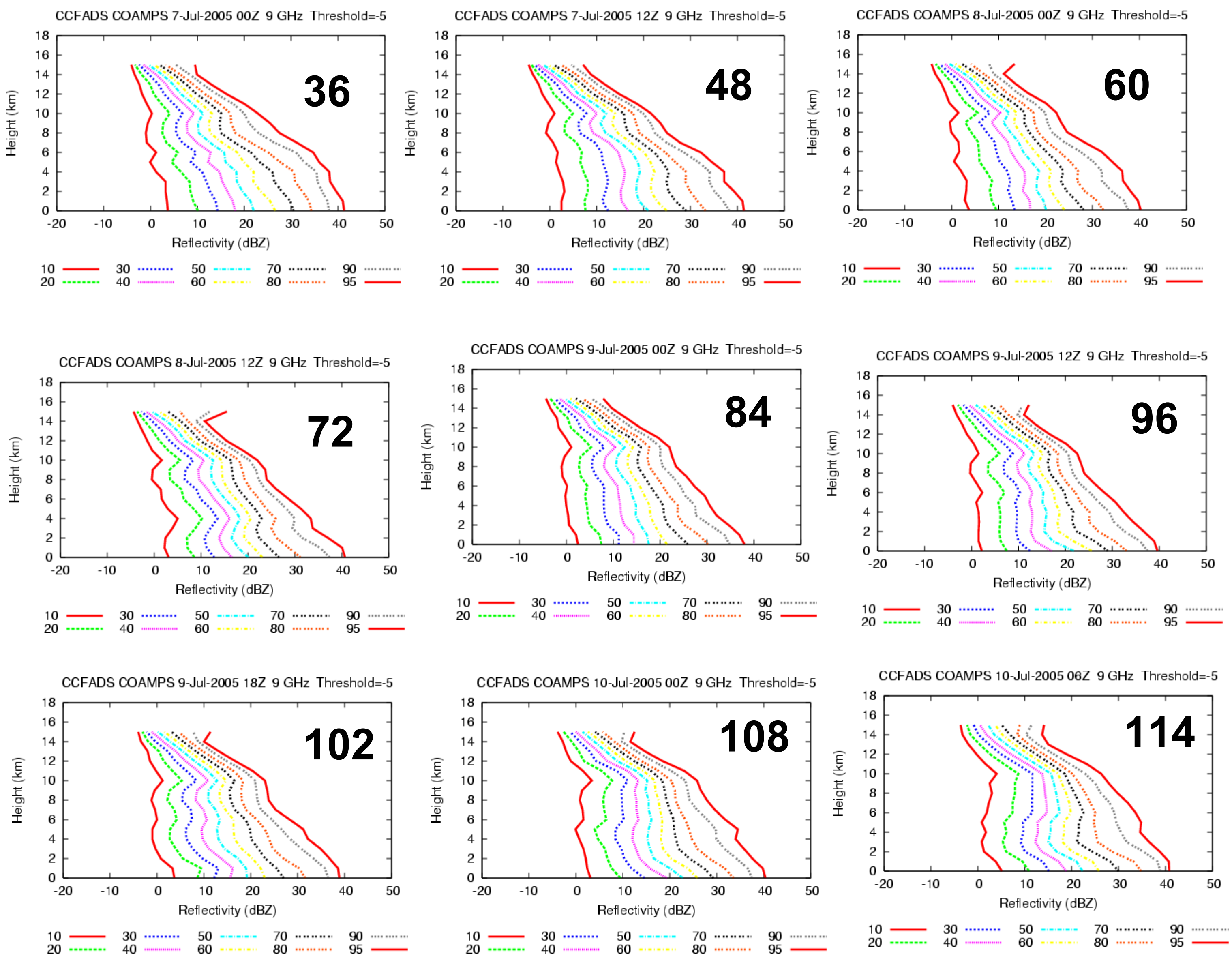






ER-2 flights were ~ 8 hours before the TRMM overpass

Model-Simulated CCFAD Sequence Beginning 2005/07/05 12 UTC



ER-2 flights were 8 hours before the TRMM overpass

Comparing Models and Aircraft Observations
Considerations

Satellite observations are often too coarse relative to model or aircraft resolution

Aircraft observations are often too fine relative to model or satellite resolution

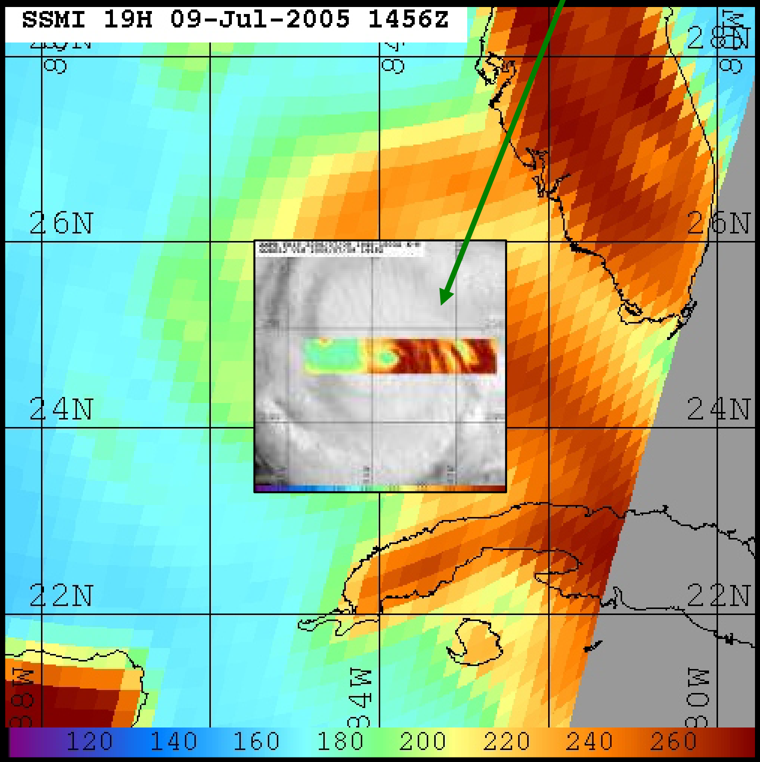
Vertical resolutions of space or aircraft radars and models are not matched

Radiometric observations represent integrated quantities

Observations are of an instantaneous nature and occur intermittently (offset in time from the model evolution)

Satellite/aircraft radars and radiometers view the scene from oblique (non-nadir) angles where the cloud three dimensionality affects the measurements

AMPR 19H from ER-2
1446-1503 UTC (1 km resolution)

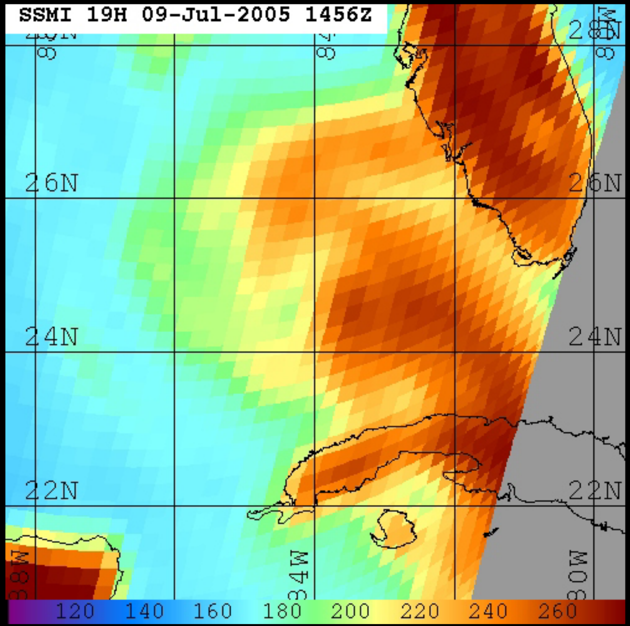


Observed SSMI 19H
1456 UTC (63 km resolution)

Comparing Satellite and Model-Simulated Observations

Observed SSMI 1456 UTC

Simulated 18 UTC (102 hrs)

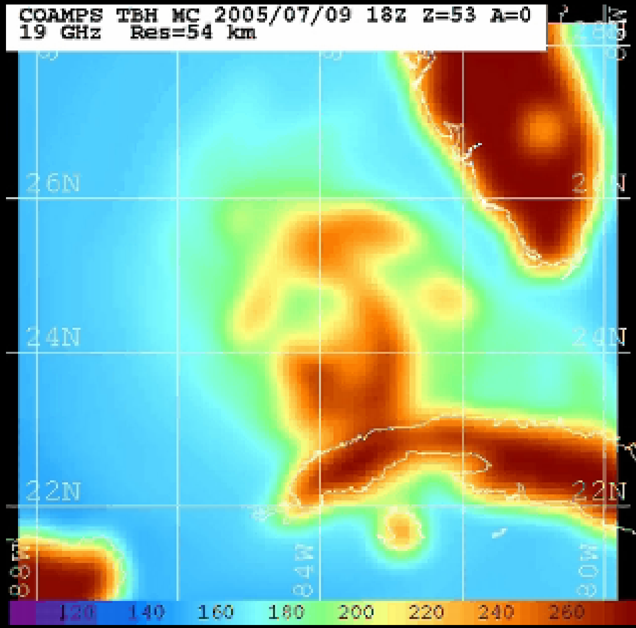


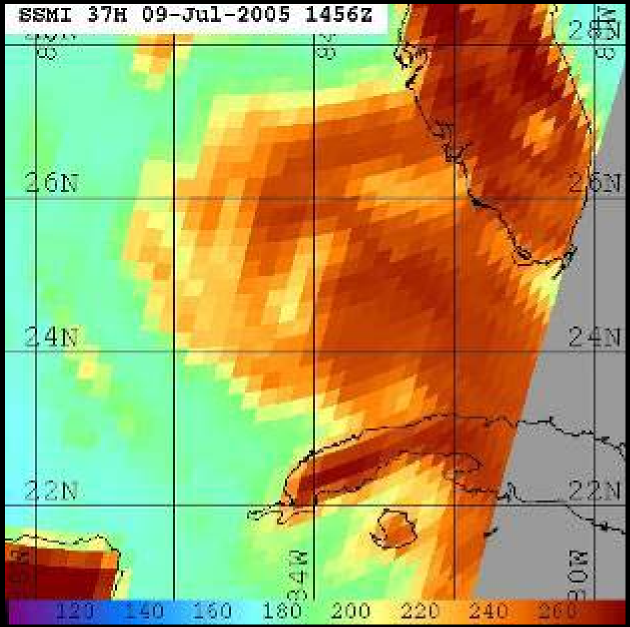
Over clear areas, SSMI > model, which suggests model is too "dry" or surface emissivity is too low (latter is most likely)

19 GHz

Coarse structure appears represented in the model, with clouds concentrated S/SE of the center

animation



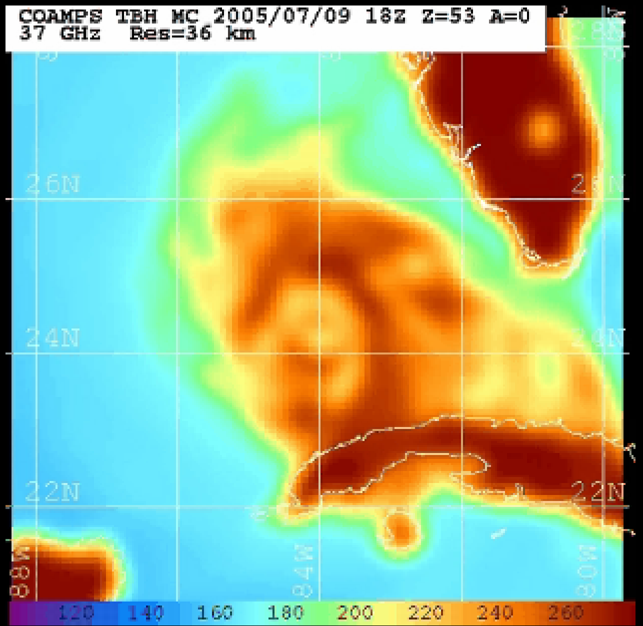


Position appears well tracked and variations in the azimuthal viewing angle don't move the "apparent center" very much

37 GHz

animation

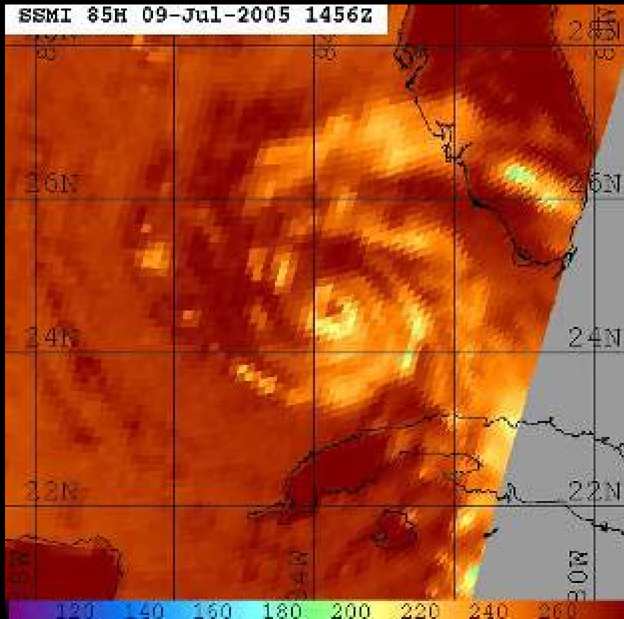
3 hours later



Comparing Satellite and Model-Simulated Observations

Observed SSMI 1456 UTC

Simulated 18 UTC (102 hrs)



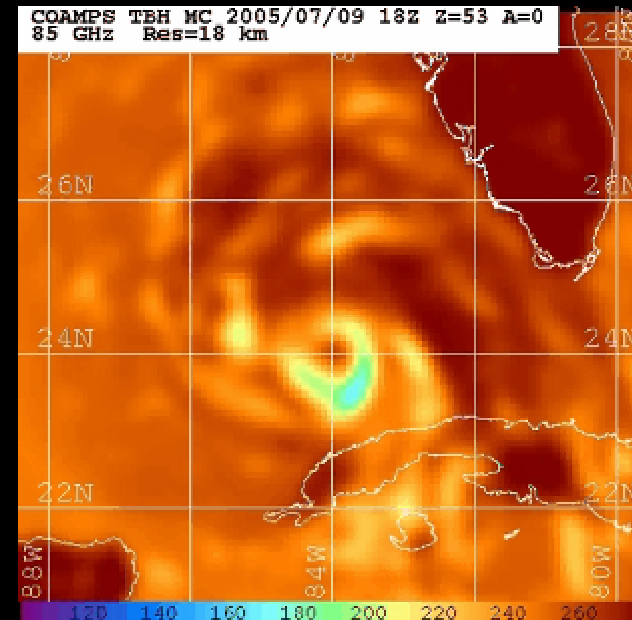
Eye dimensions appear similar

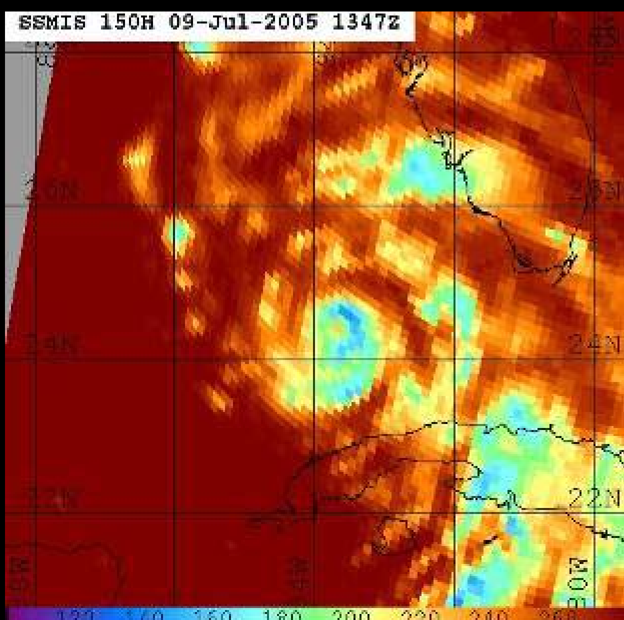
Majority of convection is located in the SE quadrant

Simulated 85 GHz is colder than observed, suggesting excessive modeled graupel

85 GHz

animation



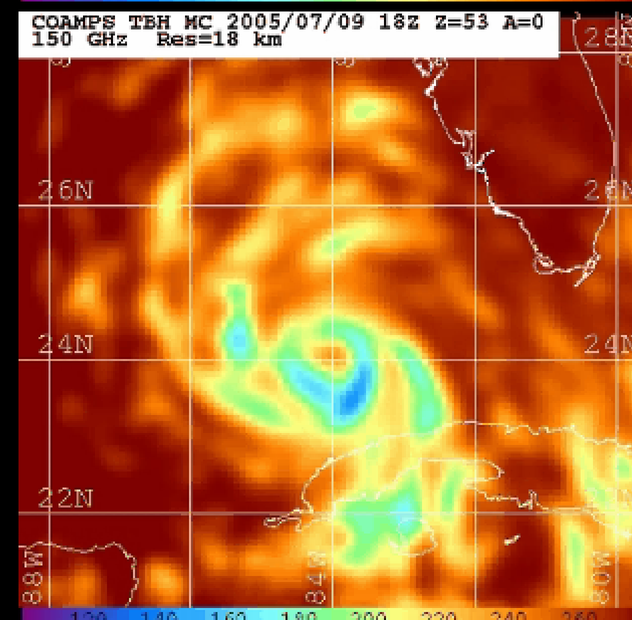


150 GHz

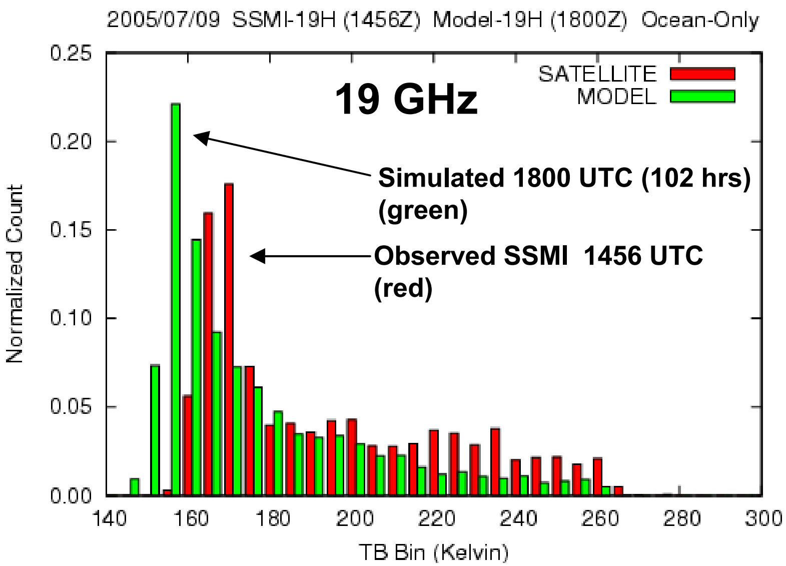
At 85 and 150 GHz, the apparent eye position moves with the azimuthal viewing direction, due to 3-D cloud geometry effects

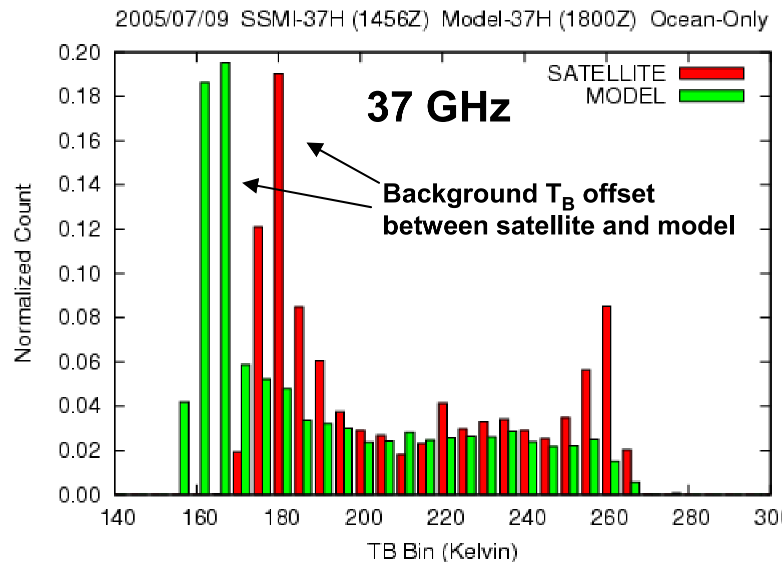
animation

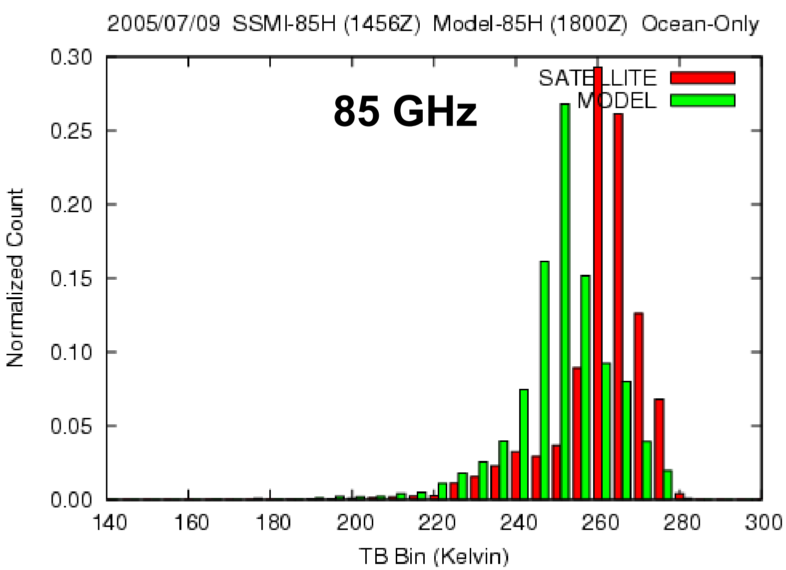
3 hours later

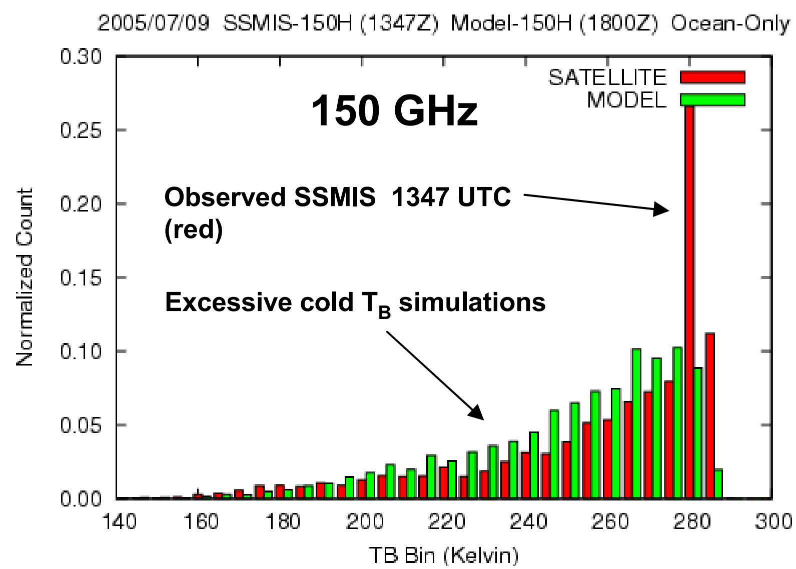


Comparing Satellite and Model-Simulated Observations   9 July 2005

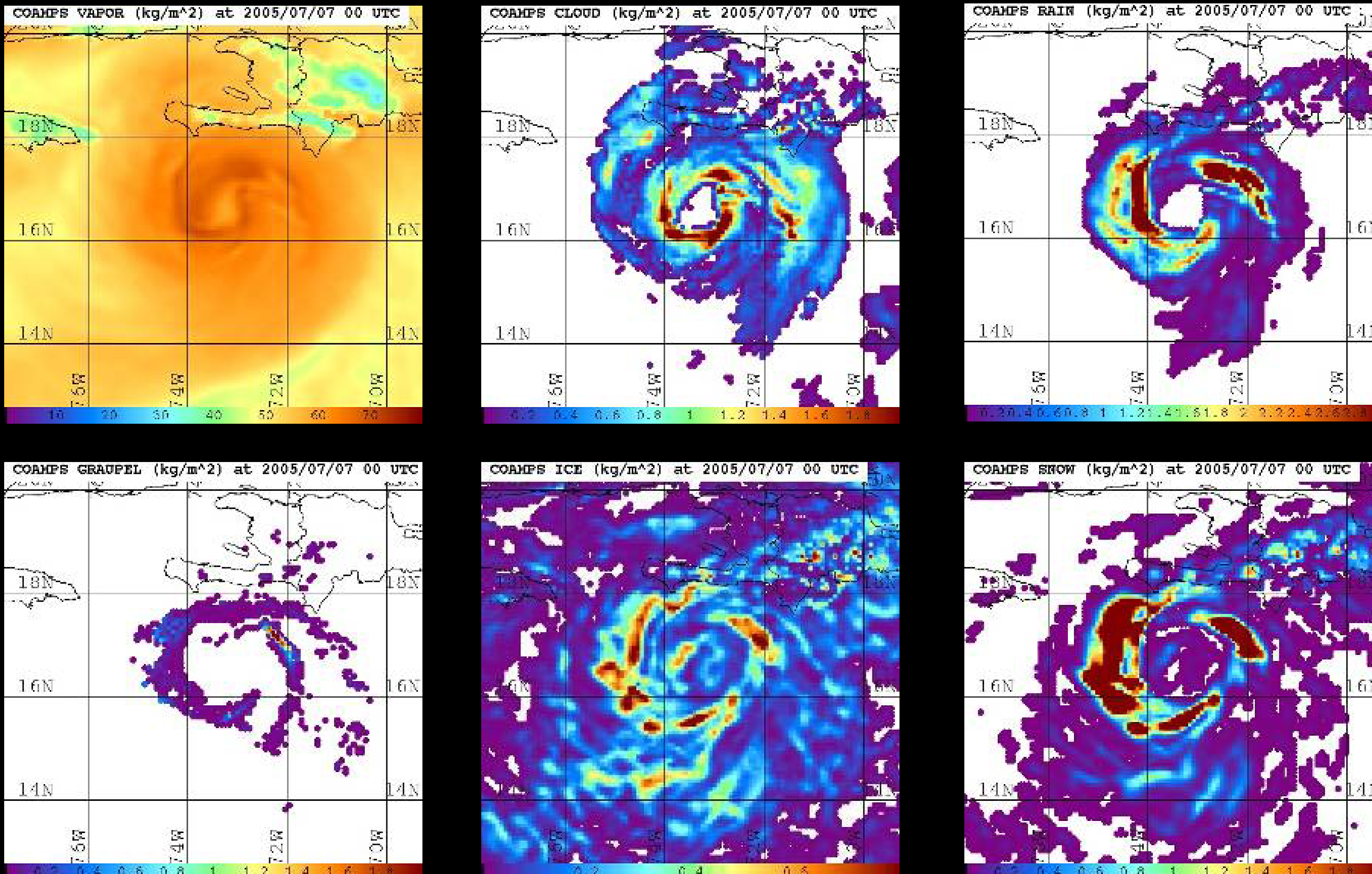






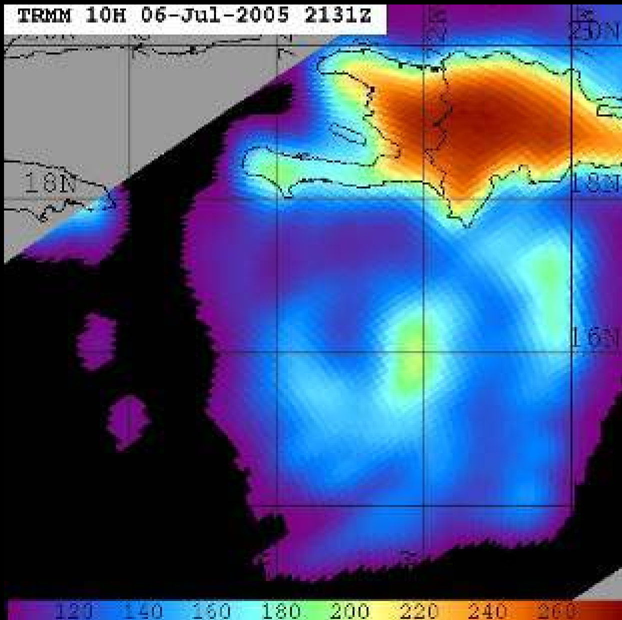


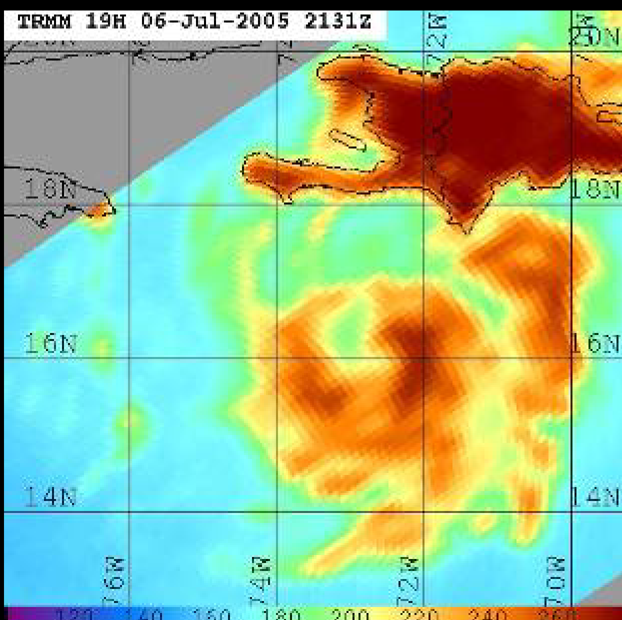
COAMPS Columnar Mass Contents   July 7 2005 00 UTC (36 hours)



Comparing Satellite and Model-Simulated Observations

Observed TRMM 2131 UTC





Position well modeled

10 GHz

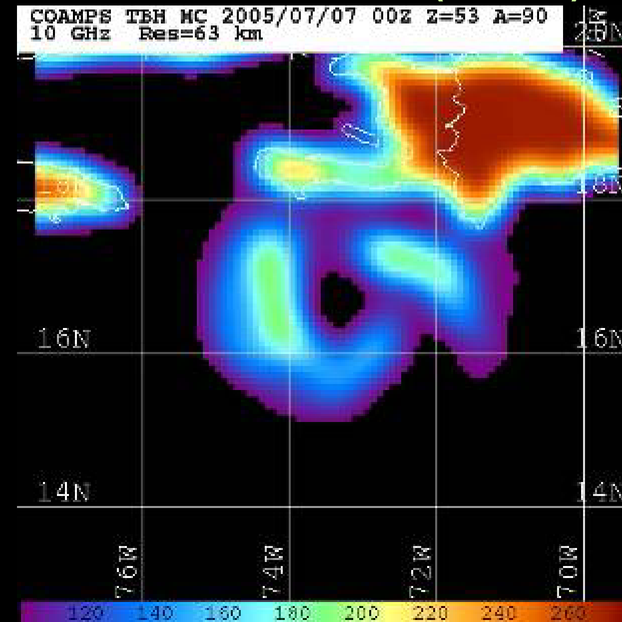
Coarse structure appears represented in the model, with an overall smaller cloud area

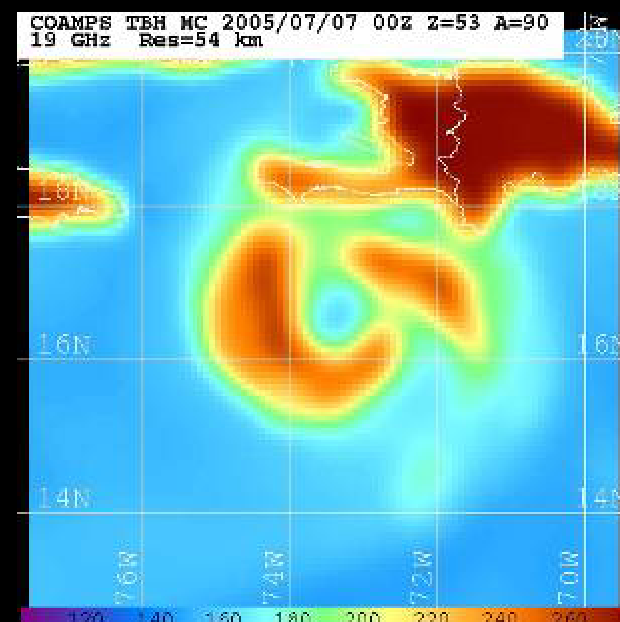
Colder modeled 10/19 GHz background T_B, similar to July 9 18 UTC time step

19 GHz

3 hours later

Simulated 00 UTC (36 hrs)

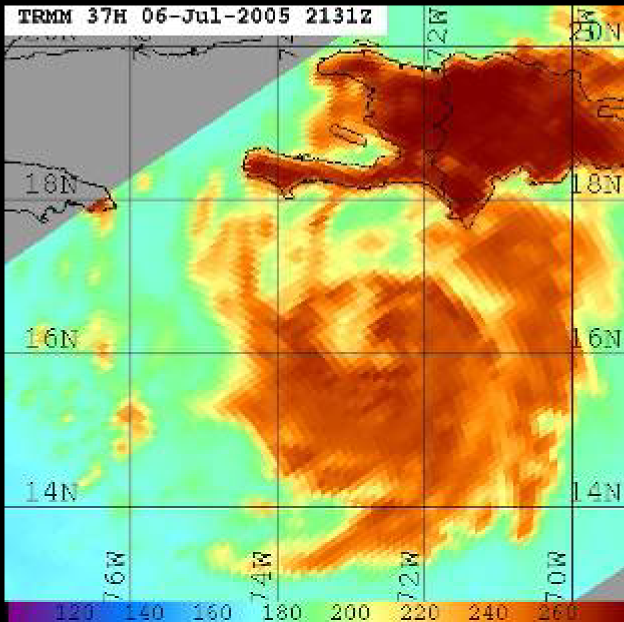




Comparing Satellite and Model-Simulated Observations

Observed TRMM 2131 UTC

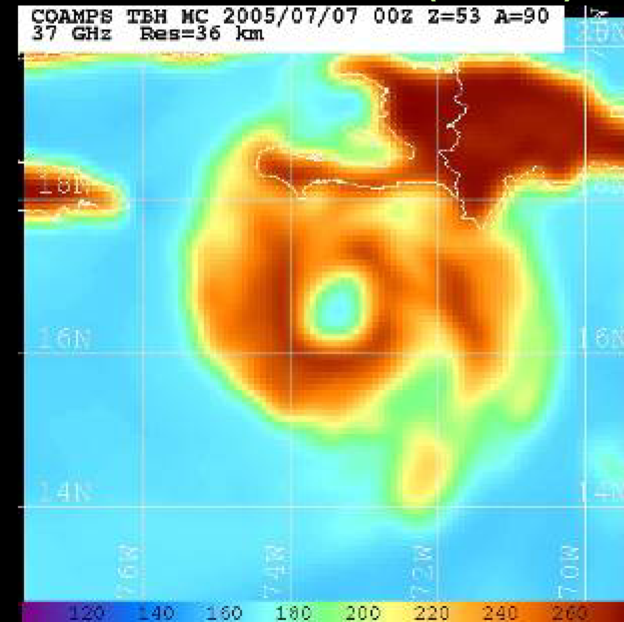
Simulated 00 UTC (36 hrs)

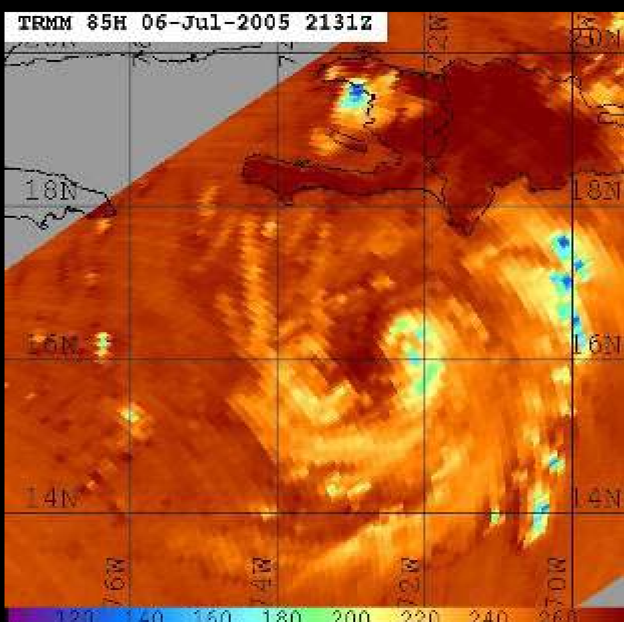


Eye dimensions appear similar

37 GHz

Simulated 37/85 GHz is more symmetric about center postion



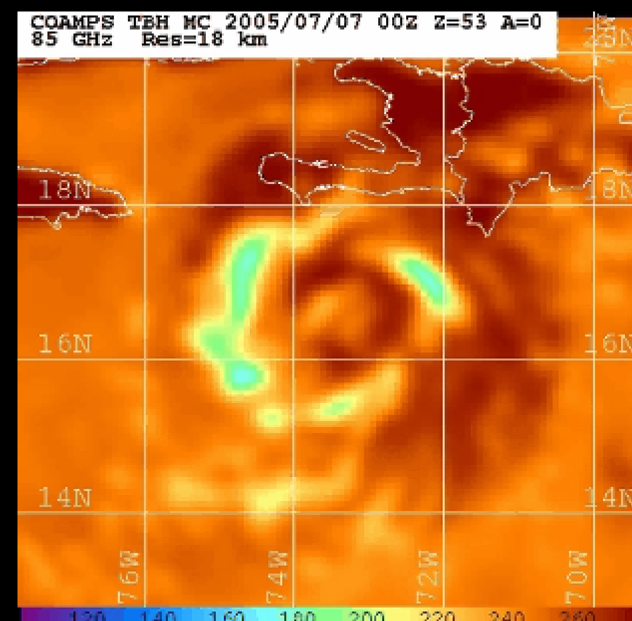


85 GHz

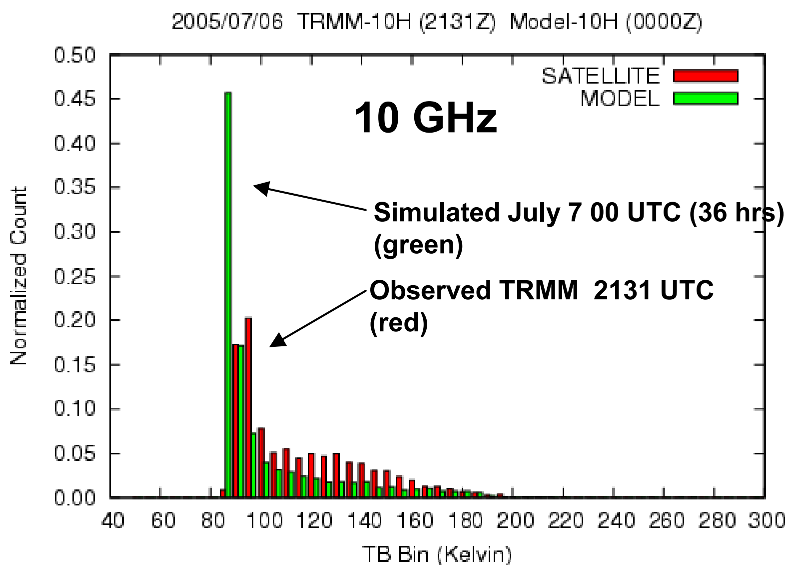
Apparent center position moves with the azimuthal viewing direction at 85 GHz, similar to July 9 time step

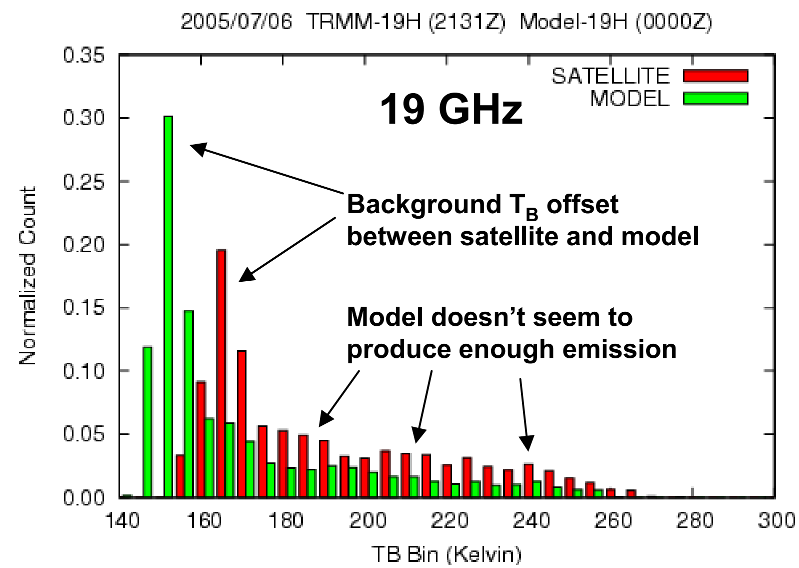
animation

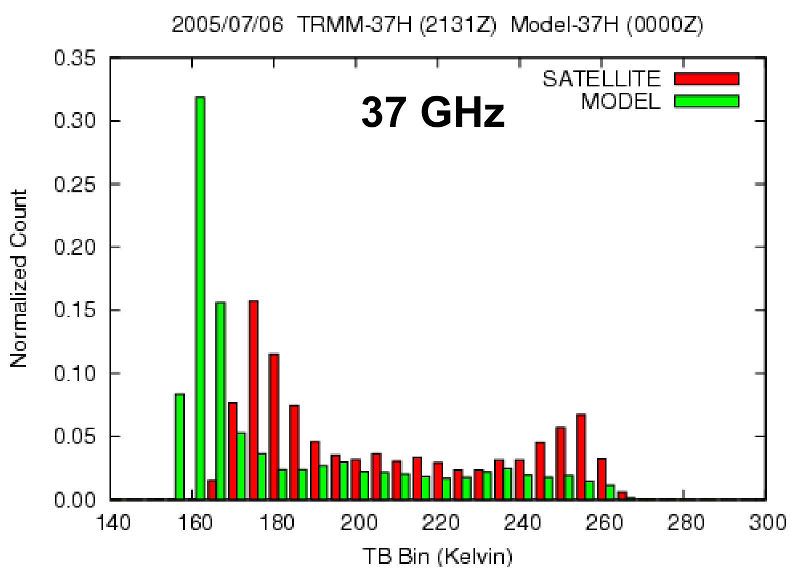
3 hours later

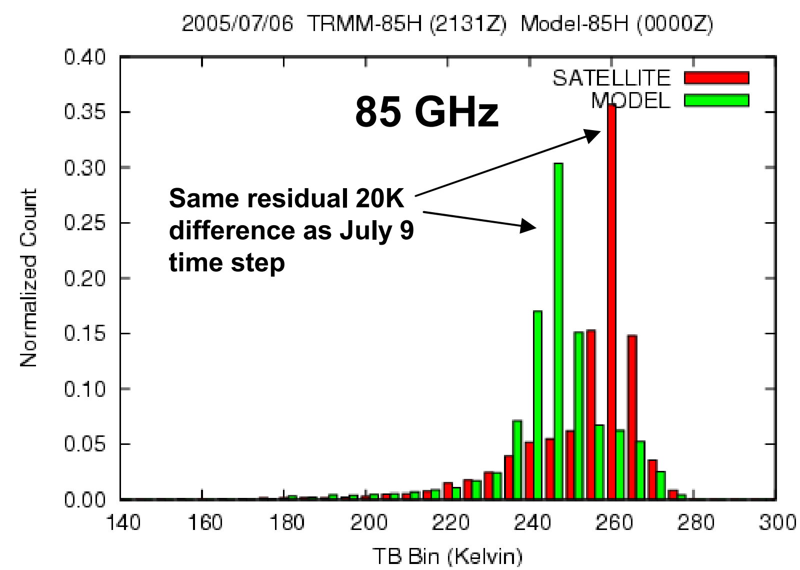


Comparing Satellite and Model-Simulated Observations 6 July 2005





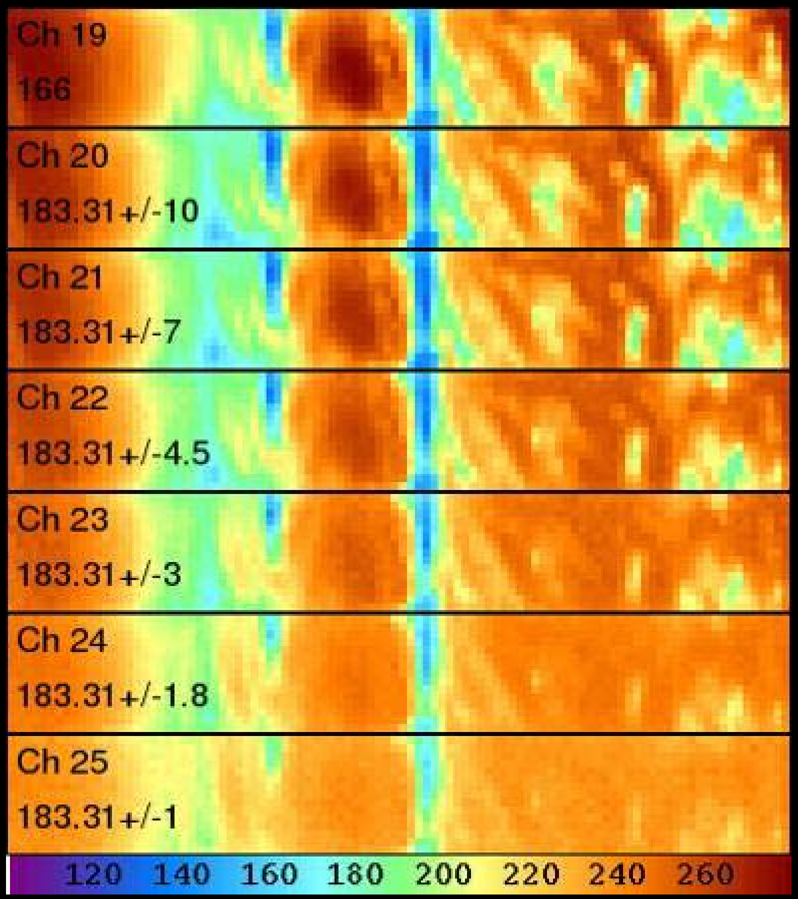




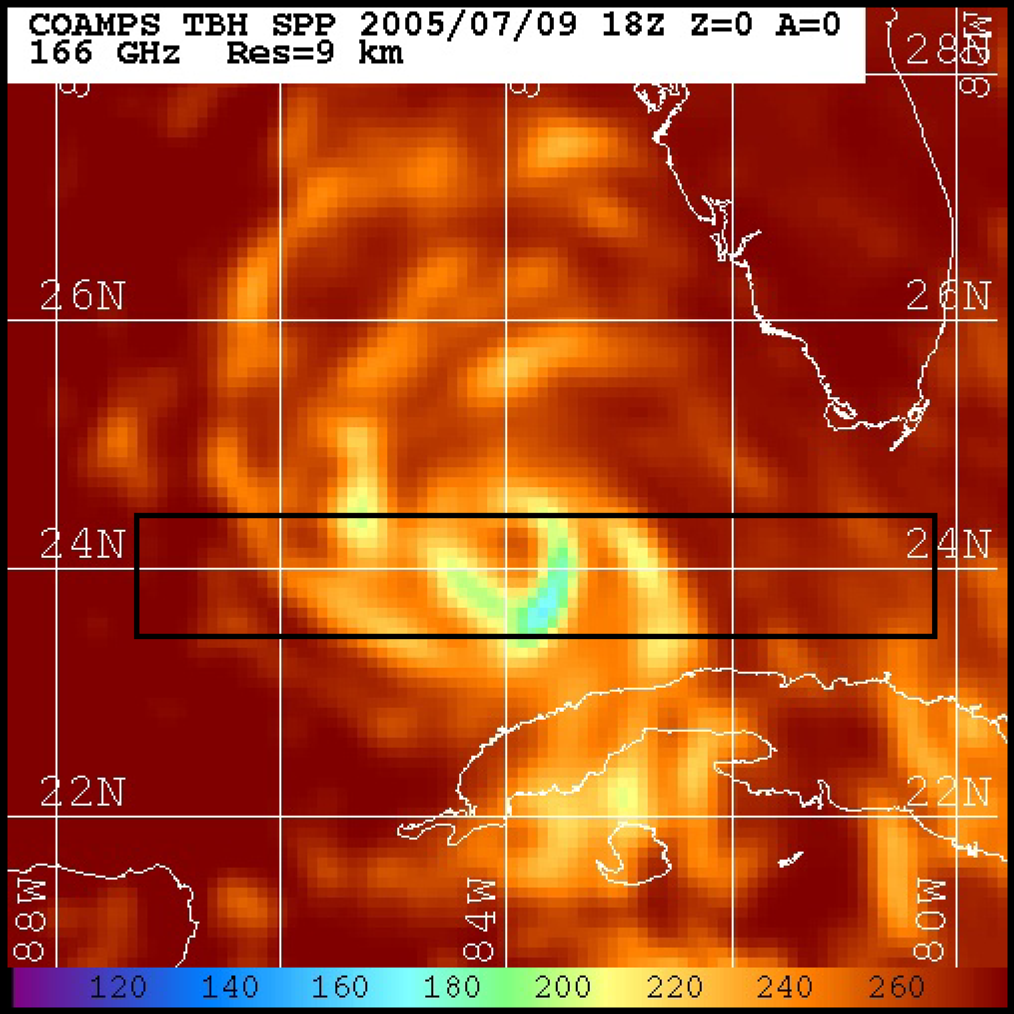
Comparing Satellite and Model-Simulated Satellite Observations

HAMSR 183 GHz Water Vapor Channels

Observed HAMSR 1446-1503 UTC



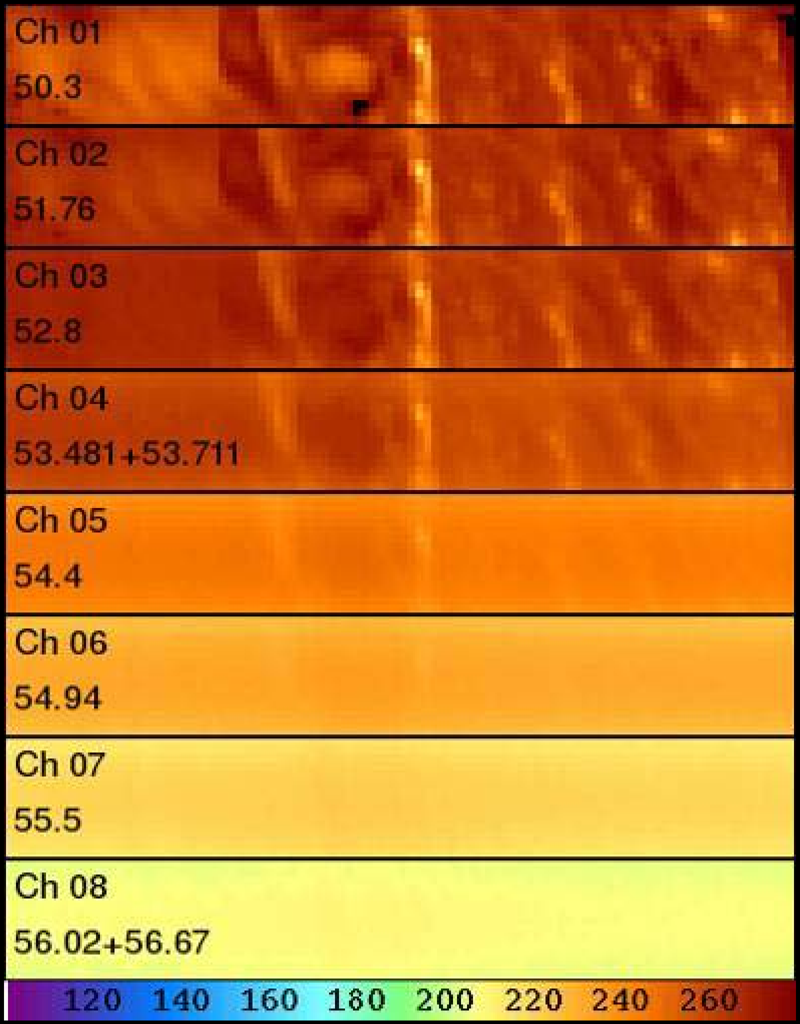
Simulated 18 UTC (102 hrs)



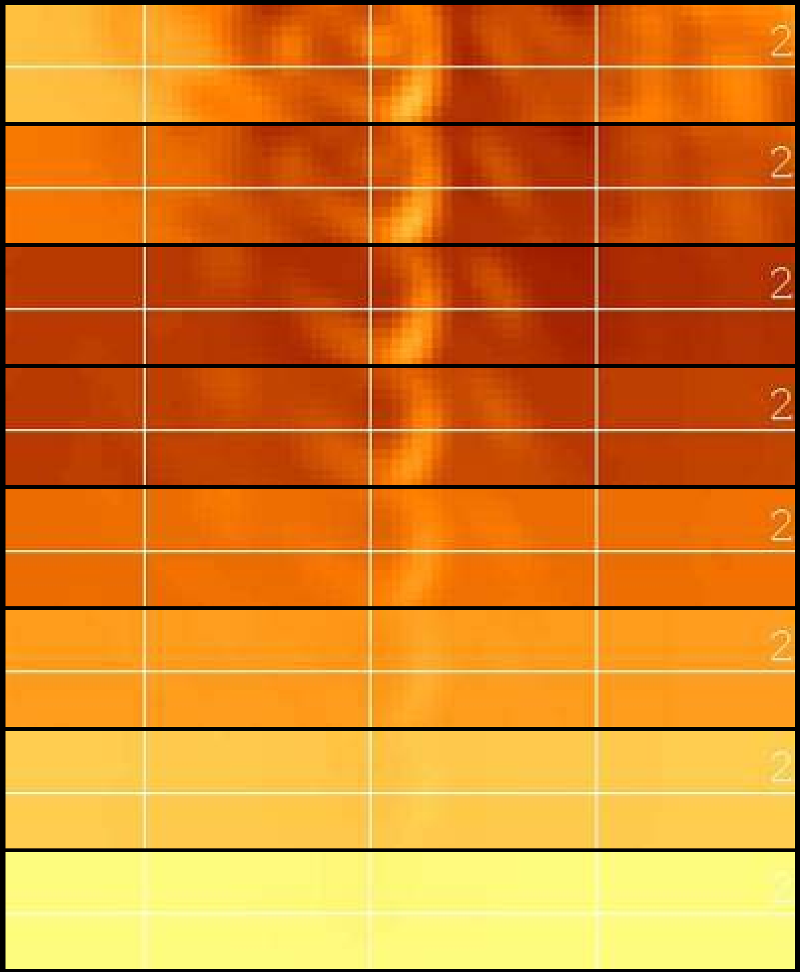
3 hours later

Comparing Satellite and Model-Simulated Satellite Observations
HAMSR 50-60 GHz Temperature Channels

Observed HAMSR 1446-1503 UTC



Simulated 18 UTC (102 hrs)



temperature at higher pressure levels

temperature at lower pressure levels

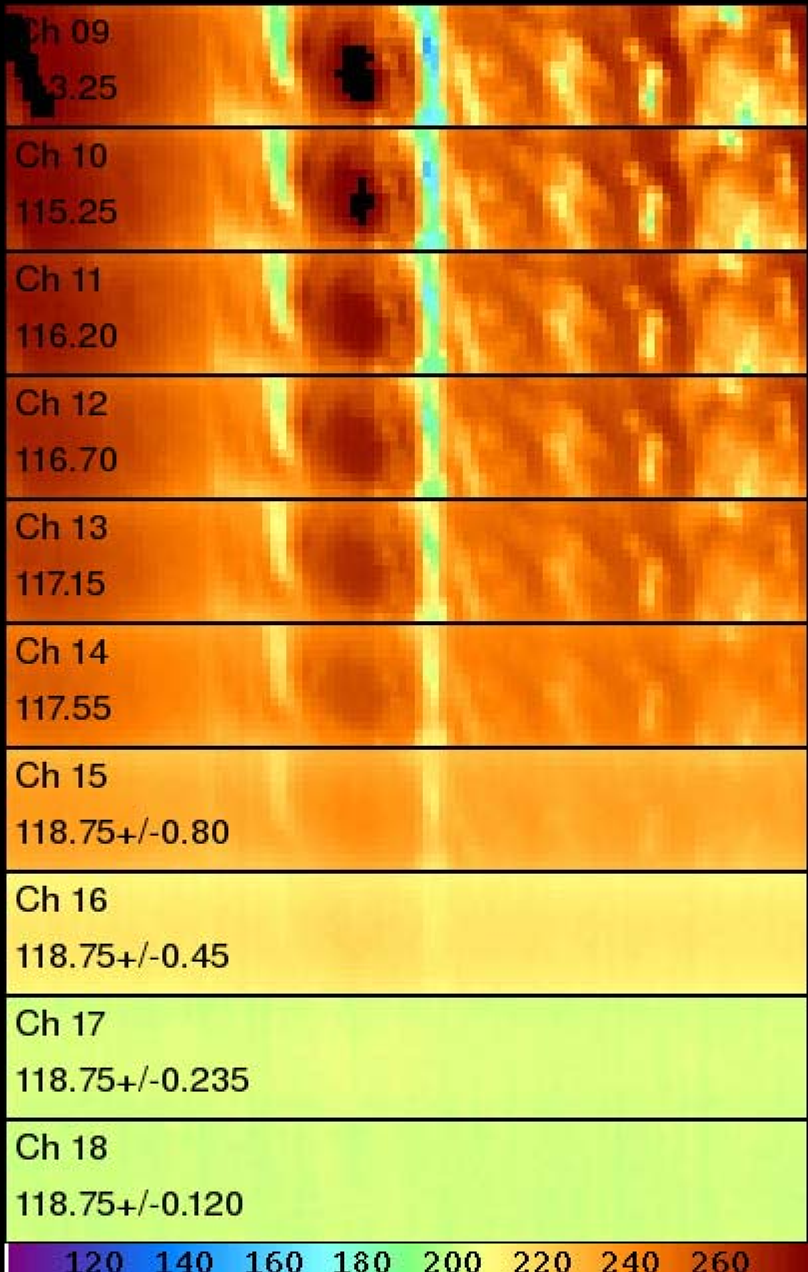
3 hours later

cropped version of full-domain imagery

Comparing Satellite and Model-Simulated Satellite Observations

HAMSR 118 GHz Temperature Channels

Simulated 18 UTC (102 hrs)

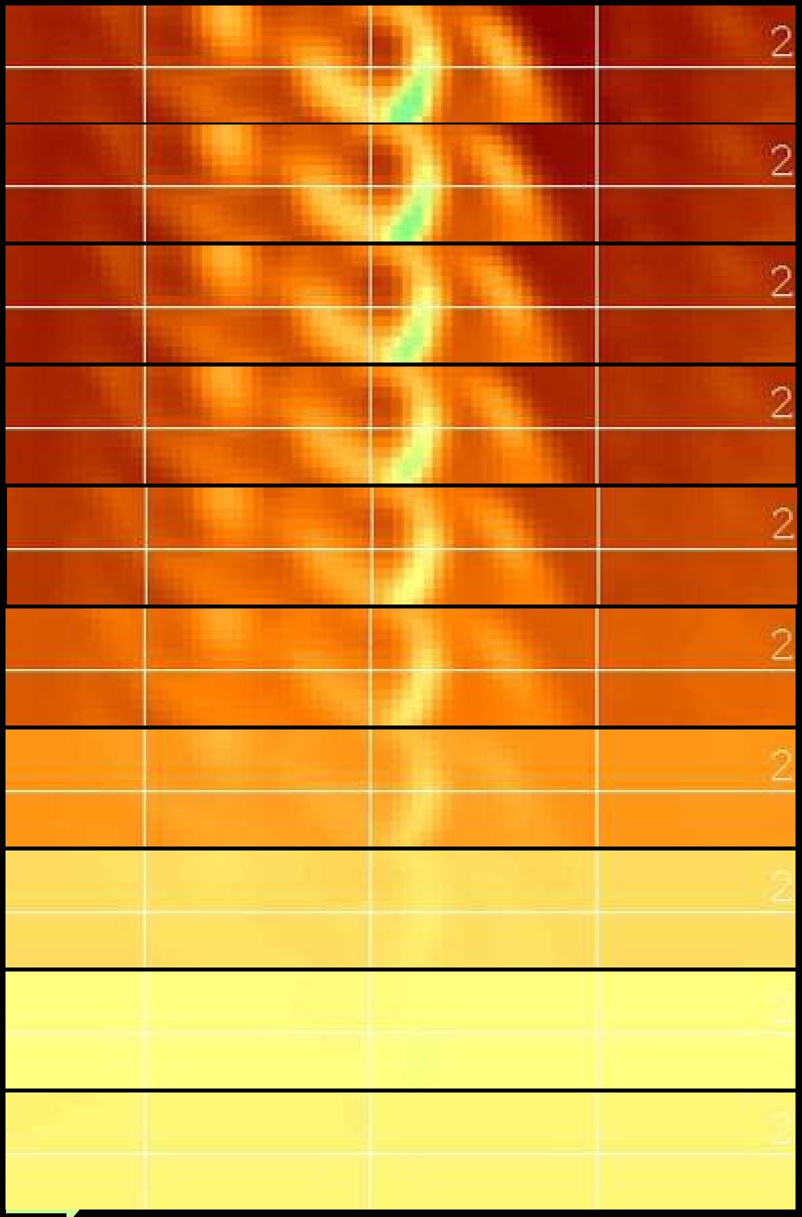


temperature at higher pressure levels

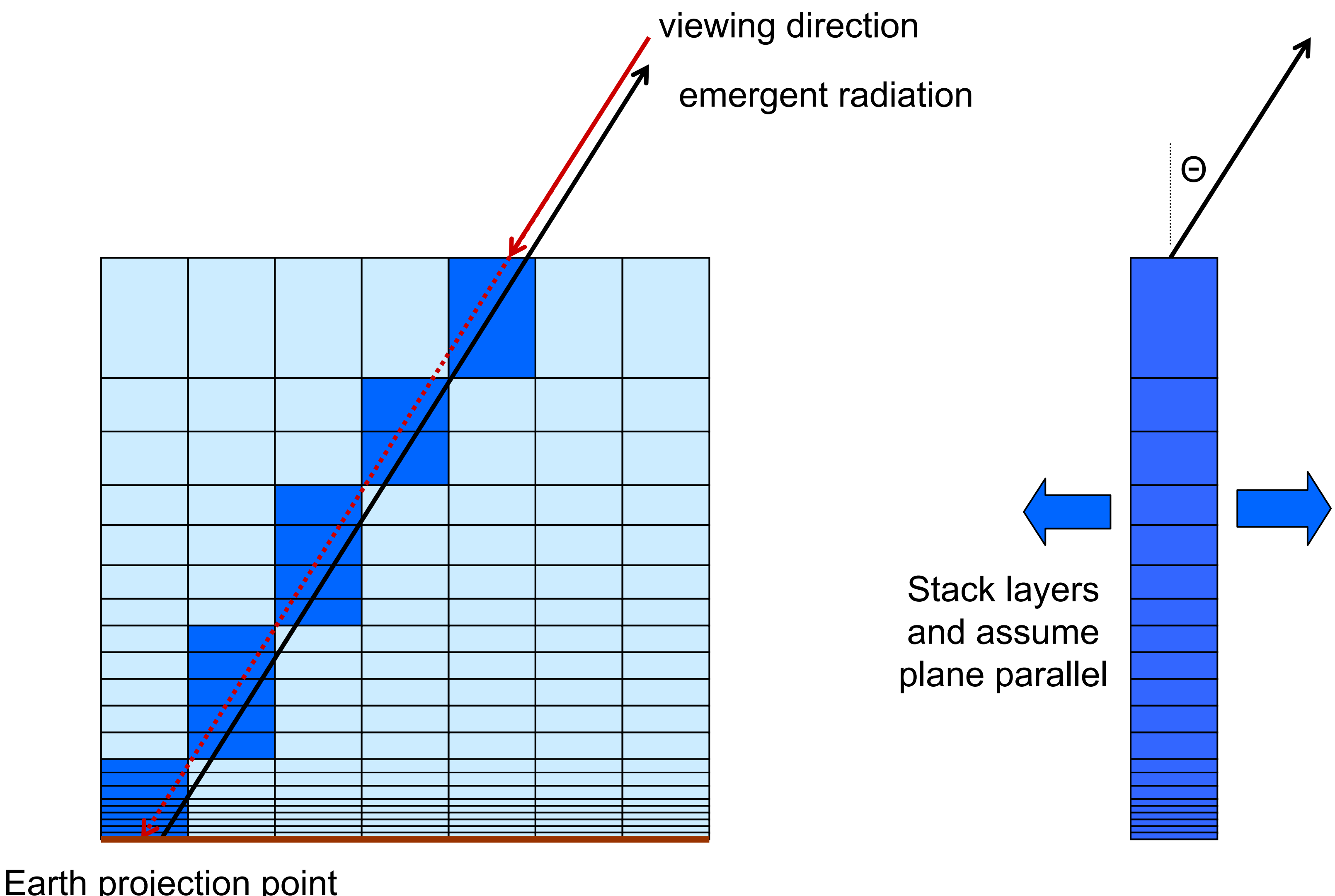
temperature at lower pressure levels

3 UTC

3 hours later



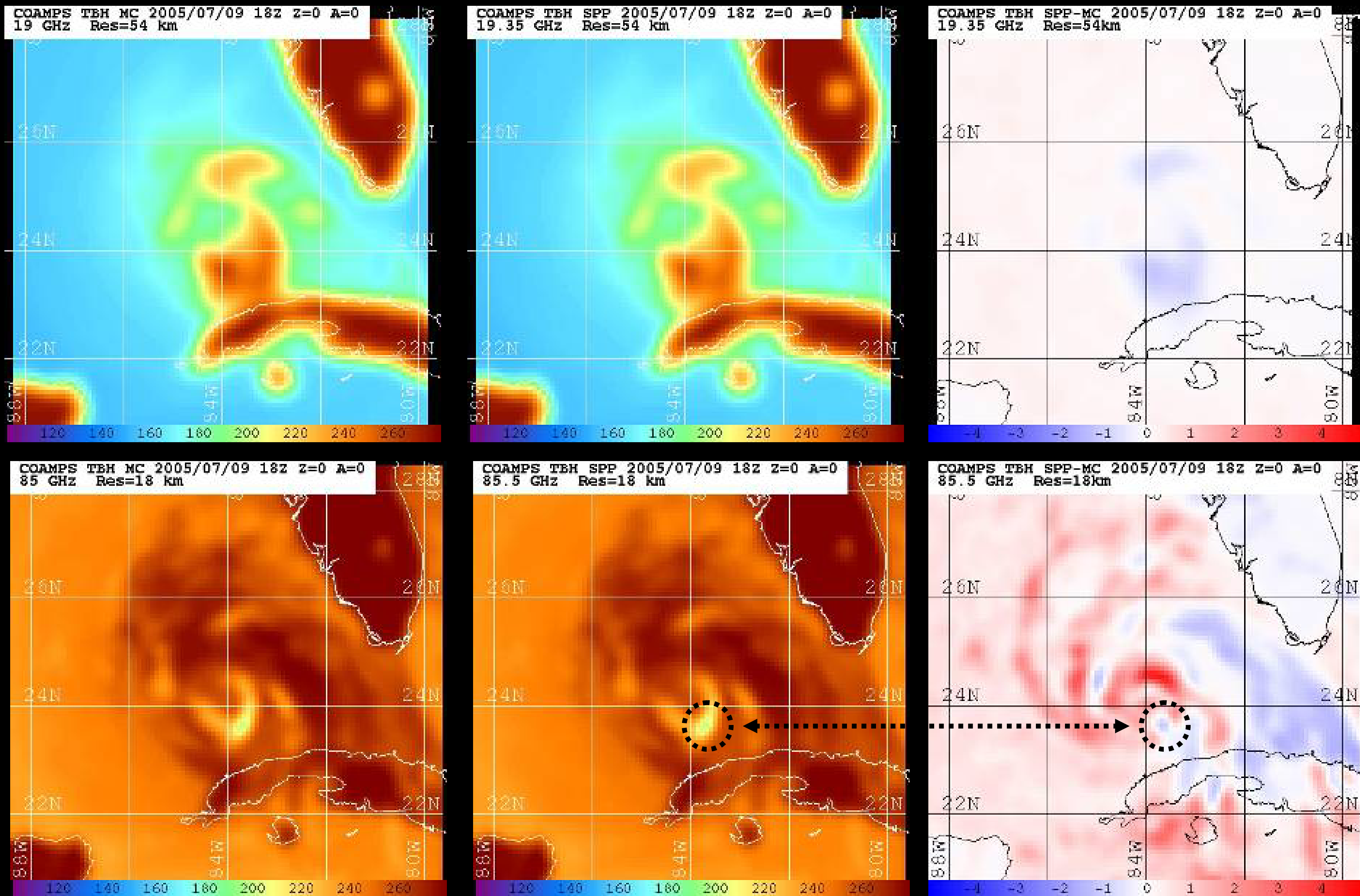
2-D slice of COAMPS Grid Along Viewing Direction
Slanted plane parallel (SPP) approximation



(not drawn to scale)

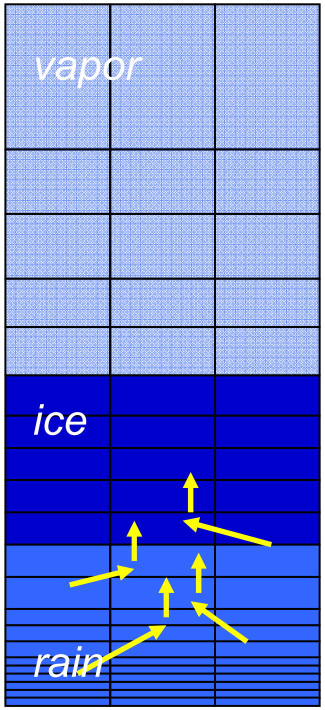
Slanted Plane Parallel Approximation (SPP) at Nadir View

19.35 GHz MC at 54-km | 19.35 GHz SPP at 54-km | SPP-MC Difference



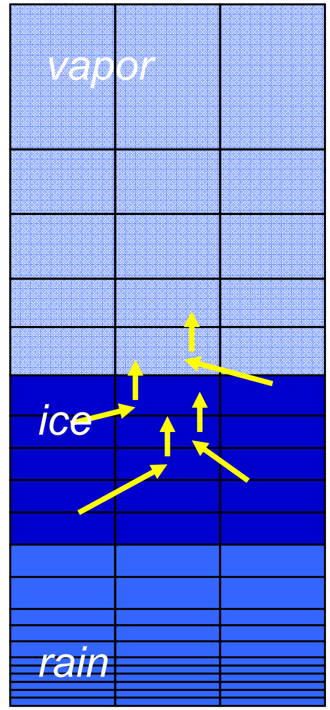
Possible Explanations for SPP-MC Differences

19 GHz



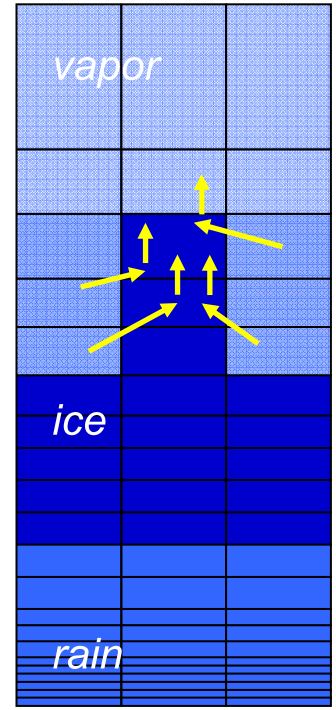
Radiometrically warm emission from neighboring columns re-enters the FOV
(MC slightly warmer than SPP)

85 GHz



Radiometrically cold emission from neighboring columns re-enters the FOV
(MC slightly colder than SPP)

85 GHz with “hot tower”



Radiometrically warm emission from upper regions of neighboring columns is scattered back into the narrow FOV
(MC slightly warmer than SPP)

However one could think of other phemonena to explain this…..

Comments (1)

- This was just one case study, and it is dangerous to conclude too much

- Computationally, it is not difficult to intercompare cloud models and satellites in radiance (or radar) space

- A slanted plane parallel model that takes cloud edges into effect should be able to replicate the sensor viewing geometry (and attenuated space radars like TRMM or CloudSat) to a first order

- Comparisons require many assumptions
  - The need to make “realistic clouds” from the model output (DSD, density, shape, etc)
  - Quiescent “background” conditions: Land surface emissivity, in-cloud surface wind speed, SST

- 10/19 GHz radiances are mainly affected by emission (total water path) and simplest to model, but rapid intensity changes are better manifested in >= 85 GHz data

Comments (2)

• A-Train sensors providing a first-ever global glimpse of vertical structure of cloud hydrometeors that TRMM is insensitive to

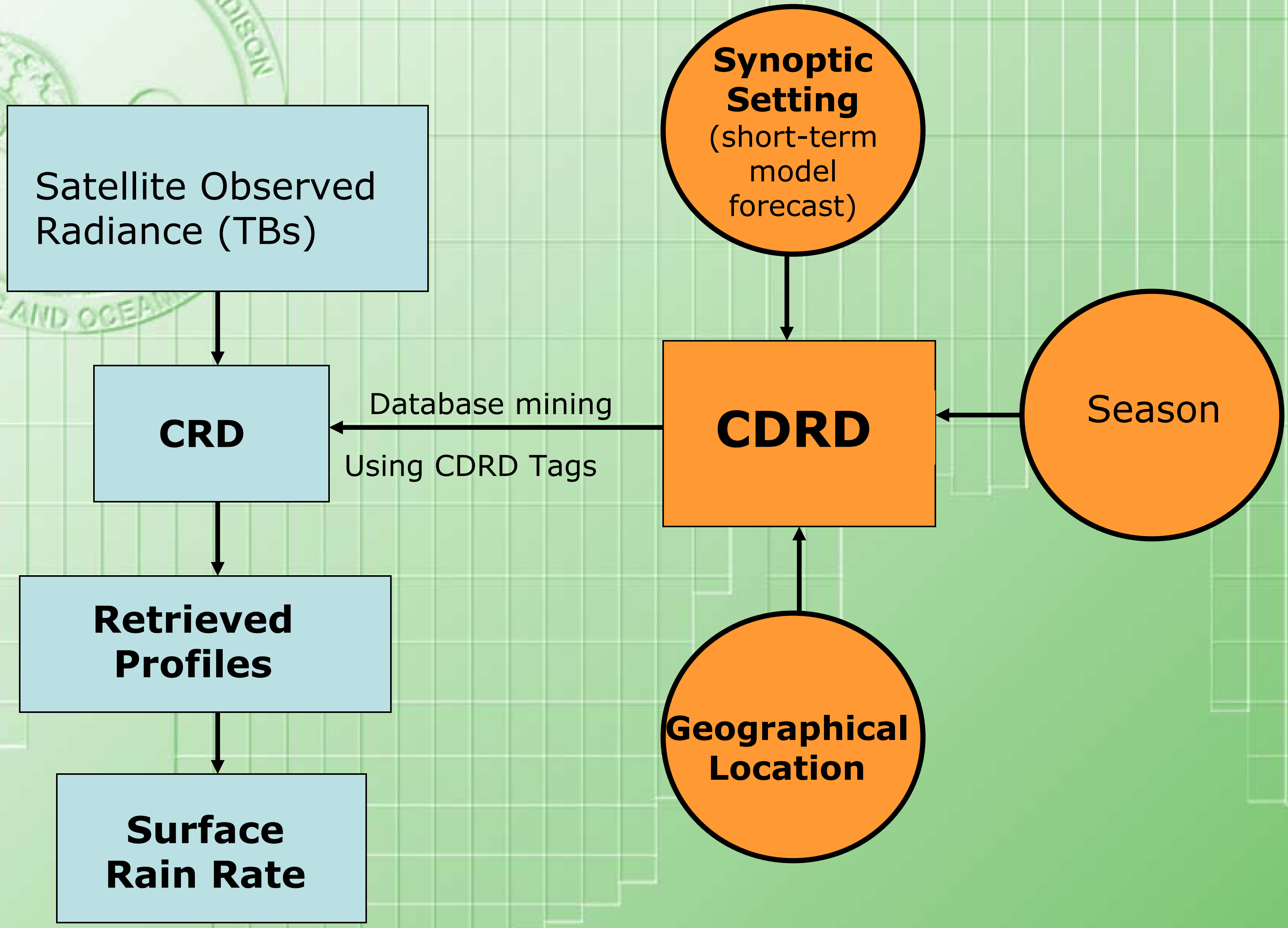
• CCFAD type comparisons give overall picture of how water is distributed in the vertical, for models and radar observations (TRMM, CloudSat)

• Really don't have a similar "common metric" for models and radiometric observations

• "Direct" intercomparisons: Match individual satellite overpasses with nearby model times (limited number of good matchups)

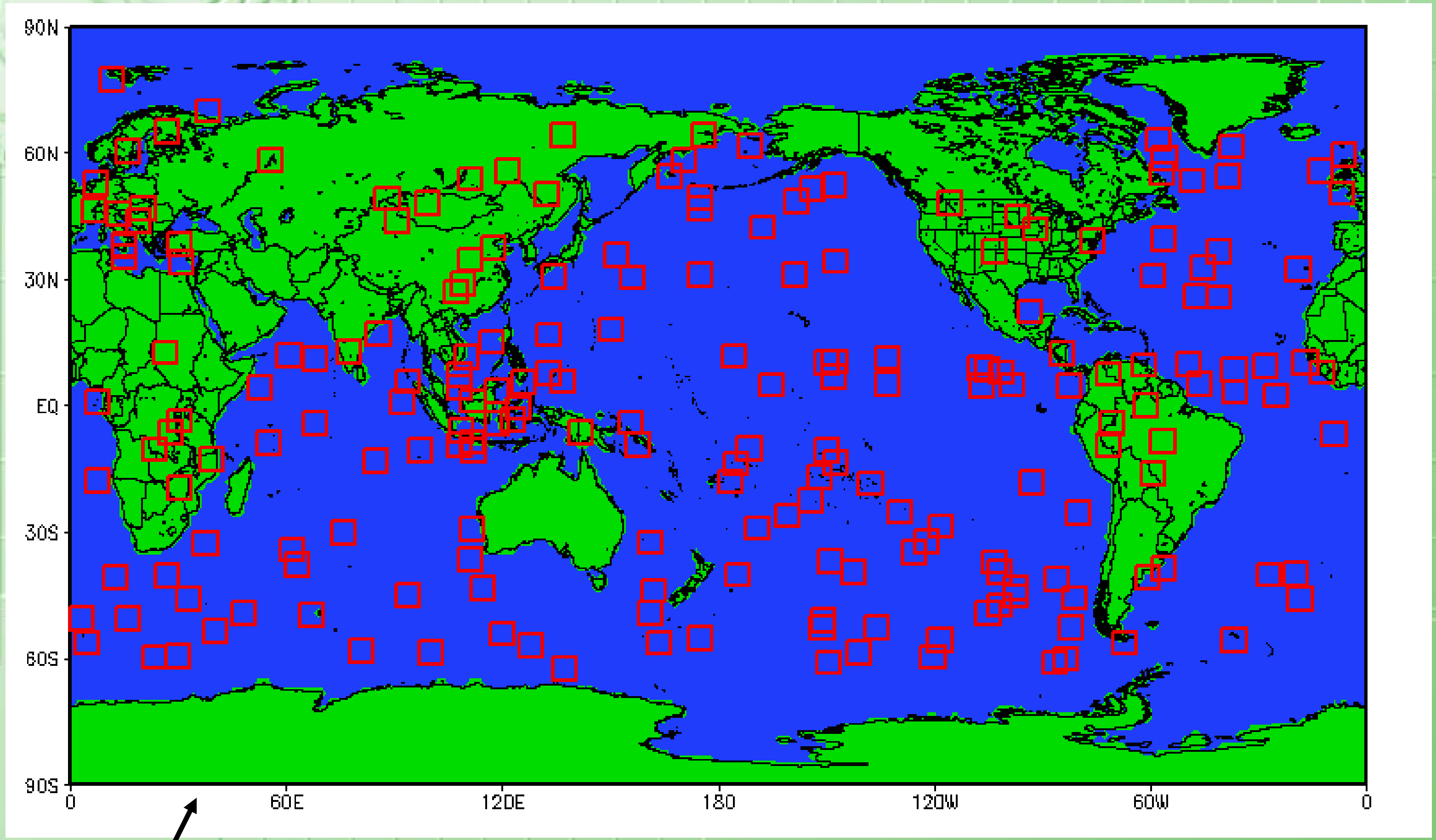
• "Indirect" intercomparisons: Analyze long term collection of satellite and model data independently in a statistical fashion (subsetted by cloud regime, season, latitude, weather event type, etc)

CDRD APPROACH



Courtesy Greg Tripoli, Univ. of Wisconsin

Global Simulation Domains



Inner Grid Locations – 2km resolution

Middle Grid – 10km

Outer Grid – 50km